Exchange Rate Pass-Through on Finnish Import Prices

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Tiivistelmä/Referat – Abstract

The linkage between the import prices and the exchange rate is an important topic in the open economy macroeconomics. However, there is a few literature focusing on the elasticity of the import prices with respect to the exchange rate especially in Finland. The aim of this study is to estimate the Exchange Rate Pass-through (ERPT) on the aggregated Finnish import prices. With the time series of Finnish Import Price Index, the aggregated foreign Producer Price Index and the aggregated foreign exchange rate index from 2001 to 2017, the analysis suggests the short-term ERPT on Finnish import prices is 36.3% and the long-term ERPT is 70.7%. Finland's domestic demand has little impact on the short-term ERPT on Finnish import prices, while it likely reduces ERPT by 1 to 5 percentage points in long term.

Avainsanat – Nyckelord – Keywords
Exchange Rate Pass-Through, Import Price Index, Open Economy Macroeconomics

Säilytyspaikka – Förvaringställe – Where deposited

Muita tietoja – Övriga uppgifter – Additional information

Contents

1. Introduction

The Exchange Rate Pass-Through (henceforth, ERPT) is the elasticity of the consumer-currency price of an import with respect to the domestic currency price of the foreign currency[1]. In other word, ERPT presents the ratio between the change of the import price and the foreign exchange rate, in the form of the importer's currency per unit of the exporter's currency. This research aims at estimating the ERPT on the aggregated Finnish import prices.

The interest to estimate ERPT is originated from the invalid application of the Law of One Price (henceforth, LOP) and Purchase Power Parity (henceforth, PPP)[2], the classical theories stating the linkage between foreign exchange rate and prices. LOP demonstrates the identical tradeable good to different destinations shall be sold in the same price in the common currency expression, when the conditions of free competition, zero (or identical) transfer cost and price flexibility are assumed. The absolute PPP holds when LOP holds for each identical product in a basket between countries A and B, and in this case, the foreign exchange rate, in the form of country A's currency per unit of country B's currency, shall equal to the quotient of country B's price index by country A's price index. However, Balassa (1964)[3], Isard (1976)[4], Kravis and Lipsey (1978)[5] and Richardson (1978) [6] all proved that neither PPP nor LOP holds in long term. Meanwhile, the researches on ERPT provide a different perspective to express the linkage between the exchange rate and prices.

Basic ERPT can be simply formulized as $\frac{\Delta Import\ Price}{\Delta E}$. This elasticity reflects the ratio of the import price responding to the exchange rate. If the import price fully responds the exchange rate, e.g. Euro to the U.S. dollar appreciates by 10% and the Finnish import price of the good exported from the U.S. increases by 10%, ERPT shall equal to 1, which also implies the validity of LOP. If the import price has zero respond to the fluctuation of exchange rate, e.g. the Finnish import price of the good exported from the U.S does not change along with the appreciation of Euro to the U.S. dollar, ERPT

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[1] The definition of the Exchange Rate Pass-Through refers to: Cook, J. A. (2014). The effect of firm-level productivity on exchange rate pass-through. *Economics Letters*, *122*(1), 27-30.
[2] The introduction of LOP and PPP refers to: Winters, A. P. (1996). International economics. Retrieved from https://ebookcentral-proquest-com.libproxy.helsinki.fi, 322-327.
[3] Balassa, B. (1964). The purchasing-power parity doctrine: a reappraisal. *Journal of political Economy*, *72*(6), 584-596.
[4] Isard, P. (1977). How far can we push the" law of one price"?. *The American Economic Review*, *67*(5), 942-948.
[5] Kravis, I. B., & Lipsey, R. E. (1978). Price behavior in the light of balance of payments theories. *Journal of International Economics*, *8*(2), 193-246.
[6] Richardson, J. D. (1978). Some empirical evidence on commodity arbitrage and the law of one price. *Journal of International Economics*, *8*(2), 341-351.

shall equal to 0. Nevertheless, in many cases, the elasticity ranges between 0 and 1, implying partial pass-through. Krugman (1986) explains the partial pass-through by “Pricing to Market” (henceforth, PTM), which refers that exporters adjust the markup towards different foreign markets in order to stabilize the prices in their customers’ currencies[7]. Therefore, the price discrimination to multiple destinations may offset the response of the import price to the exchange rate, leading ERPT smaller than 1. Local currency pricing (henceforth, LCP), referring to the sticky price in importers’ currency, further elaborates PTM against the traditional producer currency pricing (henceforth, PCP) assumption by Obstfeld and Rogoff (1995)[8]. The notable researches by Bett and Devereux (2000)[9], Engel and Roger (2001)[10] and Devereux and Engel (2002[11], 2003[12]) all employed the LCP assumption to explain the deviation from LOP.

The open economy studies since 1980s have yielded fruitful literatures on estimating and interpreting ERPT. However, most studies adopted U.S. trade data, and there were a few journals depicting the ERPT on Finnish import prices with localized product category. Hanna Freystätter (2003) applied the generalized method of moments (GMM), suggesting zero ERPT in the short run, based on 40% of firms in the export sector and 60% of firms in the import sector use local currency pricing[13]. Nevertheless, Campa and Goldberg (2005) suggested the short-run ERPT in Finland is 75% and in the long-run is 77%[14], which argues against Freystätter’s finding.

By using the data on Finnish import price index from 2001 to 2017 in Statistics Finland, this research develops the model from Campa and Goldberg’s (2005) study to estimate the ETPR on the aggregated Finnish import prices. The research is planned to be organized with the following parts: First, the literature review focuses on revising the notable findings on ERPT by a chronological

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[7] Krugman, P. R. (1986). Pricing to market when the exchange rate changes.
[8] Obstfeld, M., & Rogoff, K. (1995). Exchange rate dynamics redux. *Journal of political economy*, *103*(3), 624-660.
[9] Betts, C., & Devereux, M. B. (2000). Exchange rate dynamics in a model of pricing-to-market. *Journal of international Economics*, *50*(1), 215-244.
[10] Engel, C., & Rogers, J. H. (2001). Deviations from purchasing power parity: causes and welfare costs. *Journal of International Economics*, *55*(1), 29-57.
[11] Devereux, M. B., & Engel, C. (2002). Exchange rate pass-through, exchange rate volatility, and exchange rate disconnect. *Journal of Monetary economics*, *49*(5), 913-940.
[12] Devereux, M. B., & Engel, C. (2003). Monetary policy in the open economy revisited: Price setting and exchange-rate flexibility. *The Review of Economic Studies*, *70*(4), 765-783.
[13] Freystätter, H. (2003). *Price setting behavior in an open economy and the determination of Finnish foreign trade prices*.
[14] Campa, J. M., Goldberg, L. S., & González-Mínguez, J. M. (2005). *Exchange-rate pass-through to import prices in the Euro area* (No. w11632). National Bureau of Economic Research.

order since 1970s. Second, the introduction of Finnish import price indices emphasizes the calculation method of two types of price indices, for answering the question why this research employs the Import Price Index as the Finnish import prices, instead of the Unit Value Index as it was applied in Campa and Goldberg's (2005) model. Third, the model and the econometric method to quantify the ERPT on Finnish import prices will be presented in detail; meanwhile, three elementary-level and four aggregated-level data for the corresponding variables in the model will be discussed. The part of the Analysis and Evidence will finally bring up the empirical findings: The short-term ERPT on Finnish import prices is 36.3% and the long-term ERPT is 70.7%. Finland's domestic demand has little impact on the short-term ERPT on Finnish import prices, while it likely reduces ERPT by 1 to 5 percentage points in long term.

2. Literature Review

The development of the researches on ERPT has gone through three stages: first, researches in 1970s have collected abundant evidences of the invalidity of the Law of One Price and the Absolute Purchasing Power Parity, providing the basis of the further estimation of Exchange Rate Pass-Through. Second, from 1980s to 1990s, besides the practice in estimating ERPT from the aggregated level to the disaggregated level, the theory of Pricing to Market was introduced to explain the phenomenon based on the exporters' behaviour. Third, the researches on ERPT in 21st century have continued the interest on the firm level and mainly focus on instructing certain monetary policy with various econometric methods.

Studies on the relation between prices and exchange rate in 1970s mainly focused on investigating the validity of the Law of One Price and Purchasing Power Parity. Equation (1) depicts the LOP, where p_i is the home currency price of a product in country A, p_i^* is the home currency price of the identical product in country B, and E is the foreign exchange rate in the form of the country A's currency per unit of country B's currency. If LOP holds for all the products for both the country A and B, then the absolute PPP holds as the equation (2), where P and P^* are the aggregate price index of country A and country B respectively.

$$p_i = Ep_i^* \tag{1}$$

$$P = EP^* \quad (2)$$

The generic regression model for testing the validity of the LOP between two country A and B requires to rewrite equation (1) in logarithms as equation (3). p_t represents the logged price of the interested product in country A at the period t. X_t refers to the logged price of the identical product in the foreign country B. E_t is the logged exchange rate in the form of country A's currency per unit of country B's currency. Z_t represents other control variables. ε_t is the error term.

$$p_t = \alpha + \delta X_t + \gamma E_t + \varphi Z_t + \varepsilon_t \quad (3)$$

If the LOP holds, $\alpha = 0, \delta = 1, \gamma = 1$ would hold on the condition of measuring in different currency unit, while $\alpha = 0, \delta = 1, \gamma = 0$ would hold on the condition of measuring in the same currency unit. In addition, the empirical test for LOP also requires the home price p_t, the foreign price X_t and the exchange rate E_t cointegrated, which implies the residual ε_t is a stationary process. However, in most cases the error term cannot reject the null hypothesis of a unit root in Augmented Dickey-Fuller test. The estimation for ERPT follows the similar regression, but the distinct difference between the model of LOP and ERPT is that "many papers on the LOP, because they are testing an arbitrage condition rather than estimates of a pricing model, do not include any addition control, i.e., Z_t is empty"[15], concluded by Goldberg and Knetter (1996).

Besides the generic regression model of LOP, Isard and Richardson used the unit value and a second-difference regression respectively to test the validity of LOP. Both researches pointed out the failure of LOP. Isard (1977) compared the unit values in U.S. with the unit values of U.S. imports from Canada, Germany and Japan, and the statistic test shows that LOP narrowly holds for common-currency prices countries especially in the closely matched manufacture segment, otherwise the application of LOP is invalid. Richardson (1978) built the regression on the disaggregated commodity arbitrage in the trade between America and Canada. The finding shows that Canadian prices respond to exchange rate as much or more as the way American prices respond, on the condition of commodity arbitrage; otherwise the response fails.

[15] Goldberg, P. K., & Knetter, M. M. (1996). *Goods prices and exchange rates: what have we learned?* (No. w5862). National Bureau of Economic Research. P7.

The invalidity of PPP and LOP formed a basis for empirically estimating the pass-through effect in 1980s, where the motivation was brought from assessing the change of the currency value on both the external balance and domestic inflation in the last 1970s[16]. Theoretical study and the empirical estimation in both nation and industry level on the ERPT reached a mature stage during 1980s; meanwhile, Pricing to Market (henceforth, PTM) theory, involving the pricing behaviour in multiple markets, was introduced.

Dating back to 1977, Kreinin has brought up the methodology to estimate ERPT in his "exchange rate experience" of the Smithsonian Agreement period, where he implied the ERPT in the U.S. was 50%[17]. In 1986, Krugman's noteworthy paper applied "Pricing to Market" to explain prices discrimination in multiple markets, and suggested "35% to 40% of the real appreciation of the dollar since 1980 has been absorbed by foreign exporters in a rise in their prices to the UNS compared with prices in other markets"[18], via studying the trade between Germany and the U.S. At the same time, Hooper and Mann (1989) studied the causal relation of the exchange rate and price in the U.S. and suggested the ERPT on the U.S. imported prices was 60%[19]. Woo and Hooper (1984) applied a cost-markup model to estimate the ERPT of the import prices and the export prices separately[20]. The ERPT research concluded that reducing in the U.S. inflation was not majorly contributed from the U.S. dollar appreciation. Froot and Klemperer (1988) found that it is uncertain that the import prices respond to temporary exchange rate appreciation, but the response may be more sensitive to the expected future exchange rate[21].

The research on ERPT developed from the nation-level approach to the industry-level approach in late 1980s, along with the development of researches on imperfect competition and the strategic trade theory[22]. Feenstra (1989) studied the effect of tariffs and exchange rate on the U.S. local

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[16] Goldberg, P. K., & Knetter, M. M. (1996). *Goods prices and exchange rates: what have we learned?* (No. w5862). National Bureau of Economic Research. P9.
[17] Kreinin, M. E. (1977). The effect of exchange rate changes on the prices and volume of foreign trade. *Staff Papers*, *24*(2), 297-329.
[18] Krugman, P. R. (1986). Pricing to market when the exchange rate changes. P34.
[19] Hooper, P., & Mann, C. L. (1989). Exchange rate pass-through in the 1980s: the case of US imports of manufactures. *Brookings Papers on Economic Activity*, *1989*(1), 297-337.
[20] Woo, W. T., & Hooper, P. (1984). Exchange rates and the prices of nonfood, nonfuel products. *Brookings Papers on Economic Activity*, *1984*(2), 511-536.
[21] Froot, K. A., & Klemperer, P. D. (1988). Exchange rate pass-through when market share matters.
[22] Goldberg, P. K., & Knetter, M. M. (1996). *Goods prices and exchange rates: What have we learned?* (No. w5862). National Bureau of Economic Research. P11.

currency price of the imported vehicle from Japan, and found that "the pass-through relation varies across producrts, ranging from 60% for trucks to 100% for motorcycles" [23]. He also pointed out that the pass-through effect in tariff in long term is identical with ERPT. Giovannini (1988) presented a partial equilibrium model focusing on the determination of a monopolistic competitive firm's pricing; His research explains the cause of the ERPT by three factors: the exchange rate expectation, price staggering and ex ante discrimination[24].

Following up the fruitful studies on quantitating the pass-through effect in 1980, the researches in 1990s further developed the Pricing to Market theory raised by Krugman, and tried to explain the incomplete response of import prices to the exchange rate fluctuation by the behaviour of destination-specific markup adjustment. In other words, the focus in 1990s shifted to studying how the exporter's behaviours influence ERPT on both the nation level and industry level. Precisely, markup adjustment refers the sellers reduce (increase) the markup to buyers if the buyers' currencies depreciate (appreciated) against the seller's currency, in order to stabilize the import prices in buyers' currencies[25]. Knetter (1992) defines it as Local Currency Price Stability (LCPS).

Furthermore, a plenty of journals in 1990s argued about the source of market power and segmentation in international market, to complement the reason why the phenomenon of ERPT is common and diverse in different markets. Mann (1986) found the supplier in the U.S. had no tendency to adjust markup of the export goods[26]. Knetter (1992) rejected the hypothesis that the markup adjustment behavior is identical across industries for the U.S. and the U.K., and pointed out the markup adjustment conducted 0%, 36%, 37% and 48% of the ERPT on the import prices of the U.S, Germany, the U.K and Japan respectively[27]. Gagnon and Knetter (1995) studies the international trade of the automobile, and found 70% offset happened in Japanese auto exporters, while there were weak evidences for German and American exporters[28]. Gagnon and Knetter's findings (1995) are consistent with the previous findings by Mann (1986) and Knetter (1992).

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[23] Feenstra, R. C. (1989). Symmetric pass-through of tariffs and exchange rates under imperfect competition: An empirical test. *Journal of international Economics*, *27*(1-2), 25-45.
[24] Giovannini, A. (1988). Exchange rates and traded goods prices. *Journal of international Economics*, *24*(1-2), 45-68.
[25] Knetter, M. M. (1992). *International comparisons of pricing-to-market behavior* (No. w4098). National bureau of economic research. P2.
[26] Mann, C. L. (1986). Prices, profit margins, and exchange rates. *Fed. Res. Bull.*, *72*, 366.
[27] Knetter, M. M. (1992). *International comparisons of pricing-to-market behavior* (No. w4098). National bureau of economic research.
[28] Gagnon, J. E., & Knetter, M. M. (1995). Markup adjustment and exchange rate fluctuations: evidence from panel data on automobile exports. *Journal of International Money and Finance*, *14*(2), 289-310.

Goldberg and Knetter (1996)[29] depicted a big picture how ERPT theory evolved from the LOP to PTM, concluded that the ERPT was smaller in more segmented industries, and inferenced the sources of market power and segmentation in international markets.

The researches in the recent 20 years show a diverse application of ERPT using different econometric models. Devereux, Engel and Storgaard (2004) found pass-through is related to the relative stability of monetary policy: countries with relatively low volatility of money growth will have relatively low ERPT[30]. Ariel, Eichenbaum and Rebelo (2005) analysed the movement between the CPI-constructed real exchange rate and the relative price of non-tradable to tradable goods, where roughly 50% ERPT was observed[31]. Campa and Goldberg (2005) claimed that the ERPT was 60% one quarter after exchange rate moves and 80% after a year in Euro area. Ito and Sato (2008) examined the pass-through effects of exchange rate changes on the domestic prices in the East Asian economies via a VAR analysis[32]. Similarly, McCarthy (2007) examined ERPT on the import prices, domestic PPI and CPI in selected industrialized economies by a VAR model[33] as well. A firm-level application of the gravity model was applied for analysing the heterogeneous reaction of exporters to the real exchange rate changes in Berman, Martin and Mayer's (2012)[34] research. A heterogeneous-firm trade model was introduced by Cook (2014) to explain the low ERPT for goods traded for a short period[35].

[29] Goldberg, P. K., & Knetter, M. M. (1996). *Goods prices and exchange rates: What have we learned?* (No. w5862). National Bureau of Economic Research.
[30] Devereux, M. B., Engel, C., & Storgaard, P. E. (2004). Endogenous exchange rate pass-through when nominal prices are set in advance. *Journal of international economics*, *63*(2), 263-291.
[31] Burstein, A., Eichenbaum, M., & Rebelo, S. (2005). *How important are nontradable goods prices as sources of cyclical fluctuations in real exchange rates*. mimeo (see http://www. faculty. econ. northwestern. edu/faculty/eichenbaum/research/japan. pdf.).
[32] Ito, T., & Sato, K. (2008). Exchange rate changes and inflation in post-crisis Asian Economies: Vector Autoregression Analysis of the exchange rate pass-through. *Journal of Money, Credit and Banking*, *40*(7), 1407-1438..
[33] McCarthy, J. (2007). Pass-through of exchange rates and import prices to domestic inflation in some industrialized economies. *Eastern Economic Journal*, *33*(4), 511-537.
[34] Berman, N., Martin, P., & Mayer, T. (2012). How do different exporters react to exchange rate changes?. *The Quarterly Journal of Economics*, *127*(1), 437-492.
[35] Cook, J. A. (2014). The effect of firm-level productivity on exchange rate pass-through. *Economics Letters*, *122*(1), 27-30.

3. Finnish Import Price Indices

Producer Price Index and Import Price Index are two major indicators interested in this research. Import Price Index is one of the indicators of the producer price indices which measure the development of prices of goods and services in primary and secondary production from the perspective of enterprises[36]. Besides Import Price Index, other four separate indices, Producer Price Index for Manufactured Products, Export Price Index, Basic Price Index for Domestic Supply and Basic Price Index for Domestic Supply Including Tax, are jointly comprised the producer price indices system. The relation among the five indices is illustrated as Figure 1.

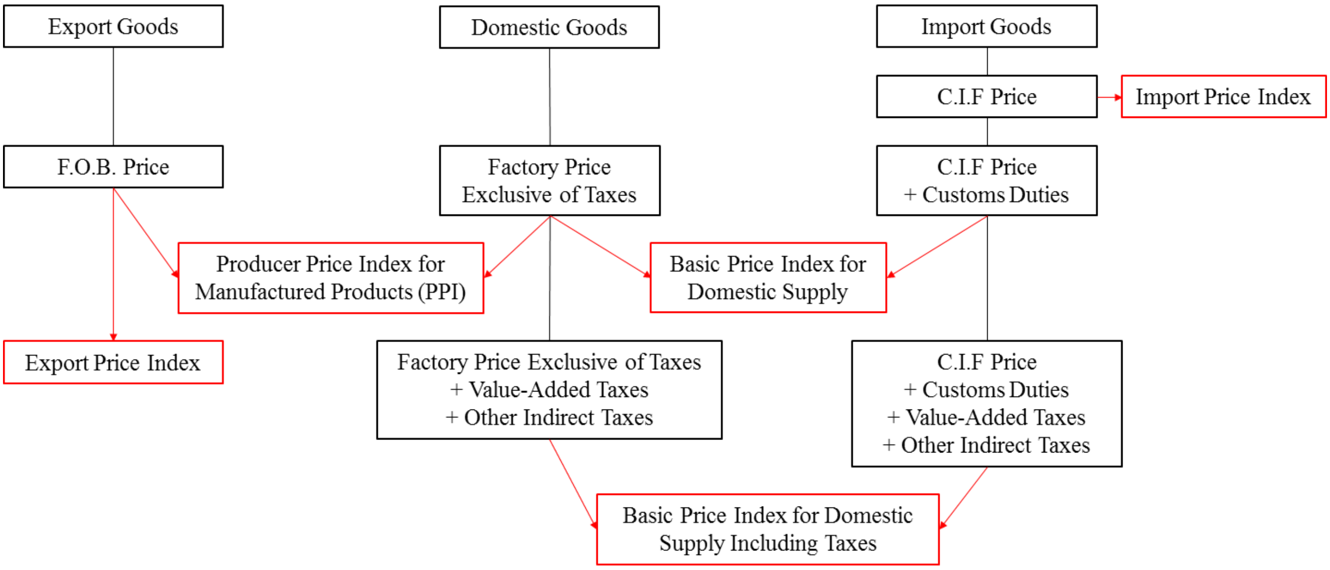

Figure 1 The Components of Producer Price Indices

As the aggregating methods of the Producer Price Index and Import Price Index are similar, the introduction mainly focuses on the import price, and particularly addresses the difference between the calculation of the Unit Value Index and the Import Price Index, two alternative indicators that can serve as the variable of Finnish import prices. The purpose of the comparison is to elaborate the reason why this research employs the Import Price Index as Finnish import prices, instead of the Unit Value Index applied in Campa and Goldberg's (2005) work.

3.1 Unit Value Index

As customer-specific currency prices, Unit Value Indices can be considered if the original of the products matters, for example, to study the ERPT at the disaggregated level in the trade between

[36] Official Statistics of Finland (OSF): Producer price indices [e-publication], 2013. P6.

only two specific countries. However, the problem is that the Unit Value Price / Index cannot be recognized as a price index as normally understood.

The calculation of the unit value index is showed as the equation (4), where $P_{UV}^{0:t}$ denotes the Unit Value Index for the commodity *i* from the period *0* to *t*; p_i^t is the price of the commodity *i* at period *t*; p_i^0 represents the price of the commodity *i* at the price reference period *0*. In other words, the Unit Value in each period is simply defined as the quotient of the total trade value on certain commodity divided by the corresponding total quantity.

$$P_{UV}^{0:t} = \left(\frac{\sum_i p_i^t q_i^t}{\sum_i q_i^t}\right) / \left(\frac{\sum_i p_i^0 q_i^0}{\sum_i q_i^0}\right) \tag{4}$$

Therefore, three points can be concluded as the reason why the unit value index cannot depict the real development of the import price: First, the fluctuation of the import prices comes from both the price itself and the type or the quality of the commodity, for example, importing a car branded Nissan at period *t* and importing a car branded Ferrari at period *t*-1 may cause the Unit Value Index at period *t*-1 is higher than period *t*, but this increase doesn't reflect the fact that the imports price got higher. Second, merely measuring the average price of a single commodity, the Unit Value Index doesn't remove the influence from the type or quality of the commodity, which causes the biased description of the price development especially for a set of heterogeneous commodities. In addition, the international trade of the homogenous commodities such as raw materials that theoretically can be measured by the Unit Value Index make up less and less of the total world traded[37].

3.2 Import Price Index

The Finnish import prices in this research are defined as the Import Price Index for estimating the ERPT at the aggregated level, which measures the development of imported goods' prices with their cost, insurance and freight (CIF)[38]. Statistics Finland is the official institution publishing the producer price indices in Finland, assisted by the National Board of Customs on data collection.

[37] Paragraph 10.88 in Export and Import Price Index Manual: Theory and Practice, International Monetary Fund, 2009.
[38] According to paragraph 10.33 in BPM6 2009, United Nation IMTS use CIF-type for imports. CIF-type valuations include: (a) "cost, insurance, and freight" (CIF) at the border of the importing country; (b) "carriage and insurance paid" to the border of the importing country.

The Import Price Index as one of the producer price indices usually serves as a deflator for Finland's National Accounts, while the National Accounts' sub-system Balance of Payments use the Unit Value (currency price) of the products for accounting. The statistics in Statistics Finland are based on the European System of Accounts ESA2010 for the National Accounts, and comply with the six edition of The Balance of Payments and International Investment Position Manual (BPM6, 2009) by International Monetary Fund. To understand the reason why it is recommended to use the Import Price Index instead of the Unit Value Price / Index at the aggregated level, it is necessary to introduce how the Import Price Index is produced. Sampling, data collection, weighting and calculation are the four basic processes. Figure 11 in the Appendix illustrated the whole process.

The calculation of the Import Price Index starts with sampling. Sampling scopes the enterprise-category-product combination to ensure the index can represent the average price development. framed by selecting enterprises, CPA categories and products for price monitoring, sampling for Finnish import prices complies with sampling for producer price indices at Statistics Finland.

Monthly price data selection is based on the scope set by sampling. Mainly collected by web-based inquiry system, price data for the Finnish Import Index, as well as the other four indicators of the producer price indices, are directly provided by enterprises. The price data from enterprises are in the form of average currency prices weighed by the sales value. Two institutions participate data collection: ① National Board of Customs gathers the data on foreign trade in goods, whose department Foreign Trade Statistics also estimates the price development of certain raw material headings with the import / export unit value prices. ② Statistics Finland collects the data on foreign trade in services, secondary income and capital transfers. Meanwhile, Statistics Finland converts the average currency prices into Euro by using the average exchange rate from the Bank of Finland.

Moreover, weight structure prepares the collected price data for the calculation of Import Price Index. The weighted structure for Finnish Import Price Index is based on the calculation of the 2010=100 renewal, and has been corrected in early 2013 on accounting of the structure change in electricity and electrical industry. In general, the weight is calculated for both the CPA product categories and the enterprises at the strata level. The bootstrapping of representative value is employed for calculating the weight for CPA product categories, which means that the weight of each category depends on the share of its gross value on that of the entire industry.

Based on sampling, data collection and weighting, the calculation of the Import Price Index is constructed from elementary aggregates, by bonding commodities and services from individual sampled enterprises into groups of relatively homogeneous commodities or services. [39] Carli index, Dutot index and Jevons index are the most widely used formulas for an elementary aggregate. The elementary aggregate and the higher-level Laspeyres Index calculation shape the resulting Import Price Index. Equation (5) and equation (6) show the two major calculations from the elementary aggregate to the resulting aggregate:

(i) Statistics Finland uses Jevons index for the micro level aggregate, which refers to the geometric averages for the CPA product categories of each enterprise[40]. Equation (5)[41] introduces Jevons index for $i = 1, \dots, n$ commodities for an individual enterprise, which is defined as the unweighted geometric mean of the price ratios. $P_{Jevons}^{0:t}$ denotes Jevons Index for the elementary aggregate of an individual enterprise; P_i^t is the price at period t; P_i^0 represents the price at the price reference period 0.

$$P_{Jevons}^{0:t} = \prod_i (\frac{P_i^t}{P_i^0})^{\frac{1}{n}} \tag{5}$$

(ii) The micro indices as Jevons index for enterprises are combined into an overall index / industry-specific index by weighting each micro index with its own weighting coefficient.[42] In other words, the trade-share of the elementary aggregate index constructs the higher-level indices as the equation (6)[43] shows, where $P^{0:t}$ denotes the higher-level price index, from period 0 to t; w_j^b denotes the weight coefficient attached to each of the micro indices, derived from the trade value in period b[44]; $P_j^{0:t}$ is the corresponding micro Jevons price index identified by the

[39] Paragraph 10.8 in Export and Import Price Index Manual: Theory and Practice, International Monetary Fund, 2009.
[40] Official Statistics of Finland (OSF): Producer price indices [e-publication], 2013. P15
[41] The formula of Jevons index refers to Paragraph 10.4 in Export and Import Price Index Manual: Theory and Practice, International Monetary Fund, 2009
[42] Official Statistics of Finland (OSF): Producer price indices [e-publication], 2013. P15
[43] The formula of the higher-level index refers to Paragraph 10.103 in Export and Import Price Index Manual: Theory and Practice, International Monetary Fund, 2009
[44] If $b = 0$, the weight and price reference period coincide, and the higher-level index is defined as Laspeyres index as equation (6). If not, the higher-level index is defined as Lowe index.

subscript j, equivalent to $P^{0:t}_{Jevons}$ in equation (5). as the producer price indices in Statistics Finland are Laspeyres index, the subscript of the weight b shall be 0.

$$P^{0:t} = \sum_j w_j^b P_j^{0:t}, \sum_j w_j^b = 1 \tag{6}$$

The calculations mentioned above give an initial Import Price Index, and there will be several revisions and corrections until figures on the Finnish national account are finalized. The initial monthly balance of payments is released approximately six weeks from the end of the statistical reference month right after the statistics on foreign trade are released. At the same time, the previous month's data will be revised once the new month's data is released. To make the monthly and quarterly data consistent with the annual level figures, the major correction of the monthly and quarterly data of the previous year happens at the end of March and September; meanwhile, the data prior to the ended year are also revised. Therefore, it takes two year to finalize the figures on the Finnish national account since the end of the statistical reference year[45].

In conclusion, sampling, data collection and weight structure have ensured the average price of a basket of the commodities is able to reflect the real price development, by removing the influence from the type or the quantity of those commodities, which is the most important difference between the Import Price Index and the Unit Value Index. Moreover, from the equation (5) to the equation (6), it shows the Import Price Index is an aggregated-level index constructed from the elementary aggregate to the higher level. Therefore, to quantify the ERPT on the aggregated Finnish import prices, it is better to choose the Import Price Index as the Finnish import price instead of the Unit Value Index.

4. Modelling

4.1 Regression Equation

A typical ERPT regression shares the same form as equation (3) to test the validity of LOP. If the change of the import prices fully responds to the change of the exchange rate, γ theoretically equals to 1, otherwise it should be smaller than 1. However, as the failure of LOP implies the null

[45] Statistics Finland, Balance of payments and international investment position, http://www.stat.fi/meta/til/mata_en.html; and Annual national accounts, http://www.stat.fi/meta/til/vtp_en.html

hypothesis of Augmented Dickey-Fuller test cannot be rejected, in the empirical study we usually use the first-differenced variables to estimate ERPT instead of using the equation (3) directly, for ensuring the residual ε_t a stationary process. Table 1 explains the estimation of ERPT in detail and compares the difference between LOP / PPP verification and ERPT estimation.

$p_t = \alpha + \delta X_t + \gamma E_t + \varphi Z_t + \varepsilon_t$	
Verify LOP / PPP	**Estimate ERPT**
p_t: The logged price of the interested product in country A at the period *t*. X_t: The logged price of the identical product in the foreign country B. E_t: The logged exchange rate in the form of country A's currency per unit of country B's currency. Z_t: Other control variables. ε_t: Error term.	p_t: The first difference of the logged local currency import price at the period *t*. X_t: The first difference of the logged exporter's cost of the identical product, converted into the importer's local currency. E_t: The first difference of the logged spot exchange rate in the form of importer's currency per unit of exporter's currency. Z_t: The control typically includes income and competing prices. ε_t: Error term.
LOP / PPP holds, when: (i) $\alpha = 0, \delta = 1, \gamma = 1$, if p_t and X_t are measured in different currency unit; (ii) $\alpha = 0, \delta = 1, \gamma = 0$, if p_t and X_t are measured in the same currency unit.	γ is the estimate of ERPT: (i) $\gamma = 1$, full response to the exchange rate; (ii) $\gamma = 0$, no response to the exchange rate; (iii) $0 < \gamma < 1$, import price partially responds to the exchange rate.

Table 1 Comparison of the Regression of LOP / PPP Verification and ERPT Estimation

Campa and Goldberg (2005) provided the intuition behind the basic regression by formulizing the expression of the Law of One Price. Equations (7) to (14) build the regression model from the basic expression of the Law of One Price, meanwhile elaborating the components of the exporter's price, marginal cost and markup. Equation (7) denotes LOP, where p_t^m is the import price; p_t^x is the export price from the home country's trading partner; e_t denotes the nominal exchange rate.

$$p_t^m = e_t p_t^x \qquad (7)$$

Equation (8) writes question (7) in logarithms, whereby the export price p_t^x is decomposed into the marginal cost mc_t^x and the markup $markup_t^x$.

$$p_t^m = e_t + (markup_t^x + mc_t^x) \qquad (8)$$

Equation (9) writes equation (8) as a regression form. The nominal exchange rate e_t is usually thought as exogenous. The pass-through is driven by the exporter's markup adjustment and the marginal prices.

$$p_t^m = \alpha_0 e_t + \alpha_1 markup_t^x + \alpha_2 mc_t^x + \varepsilon_t \tag{9}$$

Equation (10) decomposes the exporter's markup. Intuitively, if the exporter's currency depreciates (e_t gets smaller, import price p_t^mshall decrease in the importer's market), the exporter would increase the markup $markup_t^x$, for stabilizing her customer's local currency price p_t^m. Therefore, we would assume the markup is sensitive to the exchange rate as it is written in equation (10). An alternative decomposition of exporter's markup is denoted as equation (11), where g_t indicates the growth rate of domestic demand. High demand from the importer's domestic market incentives the exporter to increase the markup.

$$markup_t^x = \rho + \tau e_t \; (\rho > 0, \tau < 0) \tag{10}$$

$$markup_t^x = \rho + \tau e_t \; + \gamma g_t \; (\rho > 0, \tau < 0, \gamma > 0) \tag{11}$$

Equation (12) explains the components of the marginal cost mc_t^x as domestic demand y_t, exporter's labour cost w_t^x, exchange rate e_t and the commodity's price cp_t^x in importer's currency.

$$mc_t^x = c_0 y_t + c_1 w_t^x + c_2 e_t + c_3 cp_t^x \tag{12}$$

Substituting (10) and (12) to (9), we obtain the equation (13) as the Exchange Rate Pass-Through regression equation, with the presumption that PTM occurs in the level of industries and countries. If we substitute (11) and (12) to (9), we obtain the equation (14) as an alternative Exchange Rate Pass-Through regression equation.

$$p_t^m = \alpha_1 \rho + (\alpha_0 + \alpha_1 \tau + \alpha_2 c_2) e_t + (\alpha_2 c_0 y_t + \alpha_2 c_1 w_t^x + \alpha_2 c_3 cp_t^x) + \varepsilon_t \tag{13}$$

$$p_t^m = \alpha_1 \rho + (\alpha_0 + \alpha_1 \tau + \alpha_2 c_2) e_t + (\alpha_2 c_0 y_t + \alpha_2 c_1 w_t^x + \alpha_2 c_3 cp_t^x) + \alpha_1 \gamma g_t + \varepsilon_t \tag{14}$$

In both the equation (13) and equation (14), $(\alpha_0 + \alpha_1\tau + \alpha_2 c_2)$ is the estimate of ERPT, and $(\alpha_2 c_0 y_t + \alpha_2 c_1 w_t^x + \alpha_2 c_3 cp_t^x)$ is exactly in the form of the marginal cost as equation (12). If we compare equation (13) or equation (14) with the basic ERPT regression equation (3), $p_t = \alpha + \delta X_t + \gamma E_t + \varphi Z_t + \varepsilon_t$, the estimate $(\alpha_0 + \alpha_1\tau + \alpha_2 c_2)$ is equivalent to δ, and the marginal cost $(\alpha_2 c_0 y_t + \alpha_2 c_1 w_t^x + \alpha_2 c_3 cp_t^x)$ is equivalent to the foreign prices X_t. Equation (14) is added one more regressor, the growth rate of domestic demand, as the controlling variable. The equation (14) can be applied as the robustness check-up for the estimates yielded from equation (13).

The analysis of either the equation (13) or (14) shall still begin with testing the validity of the Law of One Price: An Augmented Dickey-Fuller test for the process, $\epsilon_t = p_t^m - e_t - p_t^x$, is supposed not to reject the null hypothesis of a unit root, and then the invalidity of LOP gives the basis to quantify the ERPT. Campa and Goldberg (2005) applied a Johansen test to assess the cointegrated relation of the import price p_t^m, the foreign price p_t^x and the exchange rate e_t in equation (7), which proved the invalidity of LOP by accepting the null hypothesis of no cointegration in most industries.

Base on the equation (13) and the model in Campa and Goldberg's (2005) work[46], equation (15) is applied to quantify the ERPT on the aggregated Finnish Import Price Index in my thesis .

$$\Delta p_t = c + \sum_{k=1}^{N_p} \alpha_k \Delta p_{t-k} + \sum_{k=0}^{N_e} \beta_k \Delta e_{t-k} + \sum_{k=0}^{N_{fp}} \gamma_k \Delta fp_{t-k} + v \tag{15}$$

p_t: Logarithmic Finnish Import Price Index at period *t*. p_t is defined as Finnish import prices.

e_t: Logarithmic aggregated nominal exchange rate index of Finland's top 15 trade partners at period *t*. The calculation of e_t refers to equation (16) in Table 2.

[46] $\Delta p_t^{ij} = c^{ij} + \sum_{k=0}^{N} a_k^{ij} \Delta e_{t-k}^{ij} + \sum_{k=0}^{N} b_k^{ij} \Delta fp_{t-k}^{ij} + v_t^{ij}$ is employed in Campa and Goldberg's (2005) work. p_t^{ij} is the logarithmic import unit value index in Euro in industry *i* in country *j*. e_t^{ij} is the nominal exchange rate for industry *i* in the form of country *j*'s currency per unit of a foreign currency. fp_t^{ij} controls the foreign competing prices in the same industry *i*; precisely, it refers to the price index of products of industry *i* into country *j* in the countries of origin of these imports and expressed in foreign currency. c^{ij} is the constant and v_t^{ij} is the error term. When *N*=0, the estimate indicates the ERPT in short term, and when *N*=4, the estimate indicates the ERPT in long term. Campa and Goldberg's model does not include the autoregression of the logarithmic import unit value index as a right-hand variable.

fp_t: Logarithmic aggregated Producer Price Index of the 15 selected Finland's trade partners at period t. The calculation of fp_t refers to equation (17) in Table 2. fp_t is defined as the foreign competing price or the exporter's marginal cost.

c: Intercept.

v: Error term.

<table>
<tr>
<th>Logarithmic Aggregated FX Index e_t</th>
<th>Logarithmic Aggregated Foreign PPI fp_t</th>
</tr>
<tr>
<td>$$e_t = ln(\sum_{i=1}^{15} \frac{E_t^i}{E_{T=2010}^i} \times w_t^i) \qquad (16)$$
E_t^i: Nominal exchange rate of Finland's trade partner i at period t, in the form of Euro per unit of the country i's currency.
$E_{T=2010}^i$: The average nominal exchange rate of Finland's trade partner i at the reference period, the year 2010.
w_t^i: Weight of Finland's trade partner i at period t, derived from the total import value.</td>
<td>$$fp_t = \ln(\sum_{i=1}^{15} FP_t^{i,2010=100} \times w_t^i) \qquad (17)$$
$FP_t^{i,2010=100}$: Producer Price Index of Finland's trade partner i at period t, and the year 2010 is defined as the reference period.
w_t^i: Weight of Finland's trade partner i at period t, derived from the total import value.</td>
</tr>
<tr>
<th>Logarithmic Foreign Aggregated Effective PPI fp_t^E</th>
<th>Weight w_t^i</th>
</tr>
<tr>
<td>$$fp_t^E = \ln(\sum_{i=1}^{15} FP_t^{i,2010=100} \times \frac{E_t^i}{E_{T=2010}^i} \times w_t^i) \qquad (18)$$
$FP_t^{i,2010=100}$: Producer Price Index of Finland's trade partner i at period t, and the year 2010 is defined as the reference period.
w_t^i: Weight of Finland's trade partner i at period t, derived from the total import value.</td>
<td>$$w_t^i = \frac{IM_t^i}{\sum_i^{15} IM_t^i} \qquad (19)$$
IM_t^i: Total import value from Finland's trade partner i, at the period t.
$\sum_i^{15} IM_t^i$: Total import value from Finland's 15 selected trade partners.</td>
</tr>
</table>

Table 2 Aggregate Method for FX, PPI and Effective PPI

Table 2 shows the calculation of the aggregated foreign exchange index e_t, aggregated foreign Producer Price Index fp_t and aggregated foreign Effective Producer Price Index fp_t^E. It is important to understand that the Effective PPI fp_t^E is an alternative indicator of the foreign competing price or the exporter's marginal cost, which describes the average development of the aggregated foreign producer prices in Euro. However, the aggregated Effective PPI will not get involved in the regression equation, as the foreign exchange index has already participated its aggregate: if use the Effective PPI as the variable of the foreign marginal cost, the coefficient $\sum_{k=0}^{N_e} \beta_k$ which indicates the ERPT likely gets underestimated. This research will use the Effective PPI as an alternative variable to test the validity of LOP and plot it as a reference to the fluctuation of Finnish Import Index. It is also necessary to point out that the selected 15 Finland's trade partners are: Germany, Sweden, Russia, the Netherlands, France, Denmark, Estonia, Belgium, the United Kingdom, Poland, Italy, Norway, the United States, China and Japan. The criteria of the selection are the total import value from 2001 to 2017. One issue concerned with the aggregate is that the data on the individual country's foreign nominal foreign exchange rate and PPI are with monthly frequency, but annual data are collected for the import value to derive the weight.

In the equation (15), the estimate of the ERPT on Finnish import price is $\sum_{k=0}^{N_e} \beta_k$, and the lag length of Finnish Import Index N_p is not necessarily the same with the lag length of aggregated foreign exchange rate index N_e and the aggregated foreign (Effective) Producer Price Index N_{fp}. $\sum_{k=0}^{N_{fp}} \gamma_k$ can be interpreted as the elasticity between the Finnish import prices and the exporters' marginal cost, but this coefficient is not what this study is interested in. The presumption is still that PTM occurs in the level of countries and industries, aligning with the research of Campa and Goldberg (2005). Table 3 explains the hypothesis in both the short term and the long term. The method to select the specific lag length N_e^* to define the long term will be discussed in the part of Econometric Approach.

Hypotheses	Short-term	Long Term
Null Hypothesis	$\beta_0 = 0$: Zero Exchange Rate Pass-Through on Finnish import prices in short term.	$\sum_{k=0}^{N_e^*} \beta_k = 0$: Zero Exchange Rate Pass-Through on Finnish import prices in long term.
Alternative Hypothesis	$\beta_0 = 1$: Full Exchange Rate Pass-Through on Finnish import prices in short term.	$\sum_{k=0}^{N_e^*} \beta_k = 1$: Full Exchange Rate Pass-Through on Finnish import prices in long term.

Table 3 Hypothesis

Equation (15) has improved the regression equation in Campa and Goldberg (2005)'s study in three aspects. First, Import Price Index is employed as the Finnish import prices. As it is mentioned in the calculation of Finnish import prices indices, Import Price Index is acquired with better capability to describe the development of the import price than Unit Value Price applied in Campa and Goldberg (2005)'s research. Second, the regression takes the autoregression of Finnish Import Index into consideration, while in Campa and Goldberg's (2005)'s research the right-hand variables didn't select lags for the import prices, which likely overestimated the ERPT on Finnish Import Price. Third, two alternative indicators for the foreign competing price or the exporter's marginal cost are taken into consideration: The one is Producer Price Index, and the other is the Effective Producer Price Index, both aggregated from Finland's top 15 trade partners. The Effective PPI is particularly aggregated from the individual PPI multiplied by nominal exchange rate index, aimed at presenting the development of the foreign competing price in Euro, the importer's currency. However, Campa and Goldberg's (2005) employed Consumer Price Index (CPI) as the foreign competing prices, of which the additional wholesales margin, retails margin and limited responsiveness make CPI a weak indicator to describe the exporter's marginal cost.

4.2 Econometric Approach

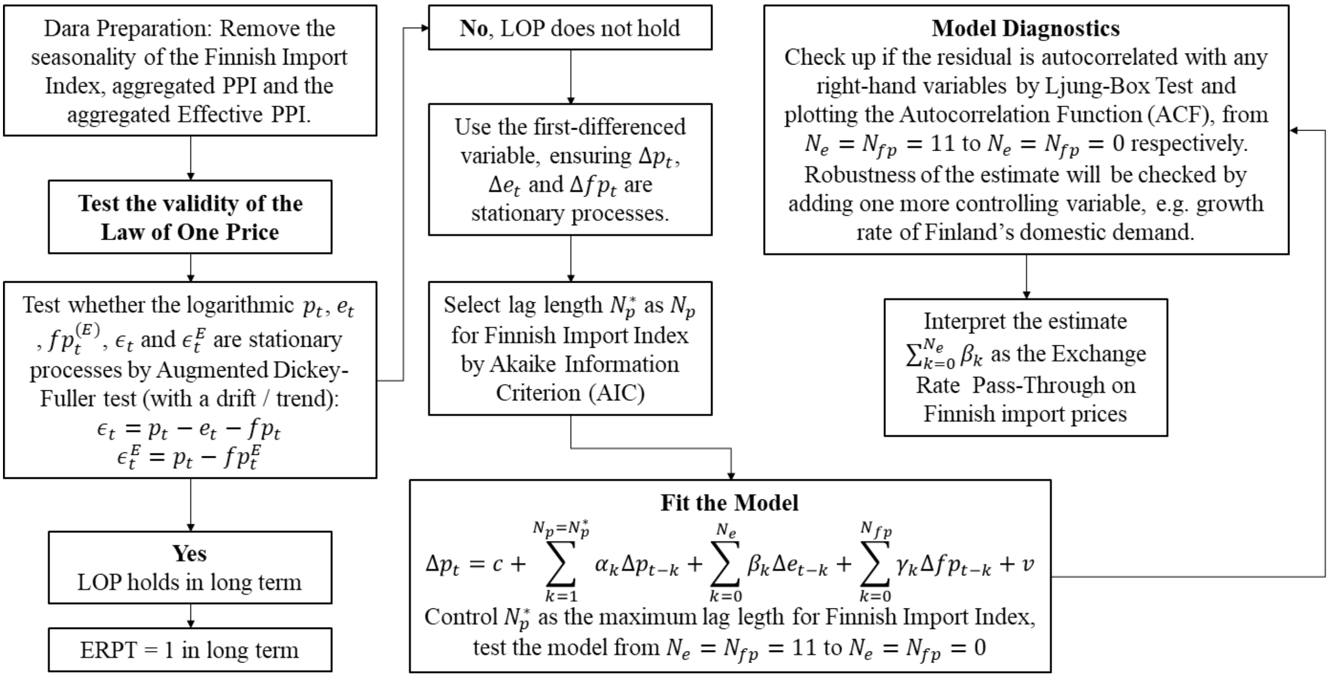

Figure 2 Research Method

Figure 2 briefly displays the major econometric approaches to estimating the ERPT on Finnish import Prices, beginning with data preparation. It is important to firstly remove the seasonality of the Finnish Import Index, aggregated foreign PPI and the aggregated foreign Effective PPI, as the original data are unadjusted. Nevertheless, it is unnecessary to adjust the the aggregated foreign exchange rate index, due to its weak seasonality. Data preparation will be reported by the decomposition plots of each variable in the Appendix. Once the data preparation has been accomplished, the first step of the analysis is to test the validity of the Law of One Price. We will simply test if the processes, p_t, e_t, $fp_t^{(E)}$, $\epsilon_t = p_t - e_t - fp_t$ and $\epsilon_t^E = p_t - fp_t^E$, are stationary by an Augmented Dickey-Fuller test (ADF test) including a drift or a trend. If the null hypothesis of a unit root in the ADF test can be rejected, it implies that LOP holds in long term and the ERPT on Finnish import prices equals 1 in long term. In other words, it can be concluded that Finnish import prices fully respond to the change of the foreign exchange rate. However, if the null hypothesis of a unit root cannot be rejected, the process is not stationary and LOP doesn't hold. Then the estimation of the ERPT based on the first-differenced variables Δp_t, Δe_t and Δfp_t will be carried out. Three major steps to fit the model (equation (15)) will be elaborated as follows:

(i) **Select the lag length of Finnish Import Index**: N_p^* as the lag length N_p for the first-differenced logarithmic Finnish Import Index Δp_t will be selected by Akaike Information Criterion (AIC). As it is mentioned that it is possible to allow $N_e = N_{fp} \neq N_p$, the selected lag length N_p^*, for the first-differenced logarithmic Finnish Import Index Δp_t, will not change along with N_e and N_{fp}, the lag length of first-differenced logarithmic FX index and PPI.

(ii) **Fit the model**: the model will be fitted by reducing the lag length of the first-differenced logarithmic FX index and the foreign PPI, from $N_e = N_{fp} = 11$ to $N_e = N_{fp} = 0$. When $N_e = N_{fp} = 0$, $\sum_{k=0}^{N_e} \beta_k$ indicates the ERPT occurs at the same period with the Finnish import prices; When $N_e = N_{fp} = 11$, $\sum_{k=0}^{N_e} \beta_k$ allows the interaction between the Finnish import prices and the aggregated FX index from the past 11 months to influence the current ERPT. Intuitively, the longer is the term to be considered, the larger will be the ERPT, since the import prices usually do not respond the exchange rate pass-through immediately. Campa and Goldberg (2002) argues that "most of the pass-through response occurs over the first and second lags after an exchange rate change, interpretation of four quarters as long run is empirically validated"[47].

[47] Campa, J. M., & Goldberg, L. S. (2002). *Exchange rate pass-through into import prices: A macro or micro phenomenon?* (No. w8934). National Bureau of Economic Research. P10.

(iii)**Define the maximum lag length of the long-term ERPT**: After we fit the model by reducing 11-lag length to 0-lag length of the first-differenced logarithmic FX index and foreign PPI, we plan to select the k^{th} lag, whose corresponding coefficient of the FX index β_k first becomes significantly different from 0, as the maximum lag length of the long term. For example, if whenever we fit the model from the 11^{th} lag, the 10^{th} lag or the 9^{th} lag to the 0 lag, the first coefficient of the FX index which comes to be significantly different from 0 is always located at the 2^{nd} lag, then we would define the "long term" is equivalent to the current period with 2-lag length, in total one quarter. In this case $\sum_{k=0}^{2} \beta_k$ will be the estimate of the long-term ERPT.

Following the model fitting, the model diagnostics will be carried out and particularly address two aspects: whether the residual is autocorrelated with the regressors, and whether the estimate of the ERPT, the sum of the coefficients of the FX index $\sum_{k=0}^{N_e} \beta_k$, is robust enough. The residual diagnostics is planned to be reported by both the Ljung-Box test and the Autocorrelation Function (ACF). The robustness of the estimate will be checked by adding one more controlling variable to the original model. Based on the equation (14), the robustness check will apply equation (20) as the regression model.

$$\Delta p_t = c + \sum_{k=1}^{N_p} \alpha_k \Delta p_{t-k} + \sum_{k=0}^{N_e} \beta_k \Delta e_{t-k} + \sum_{k=0}^{N_{fp}} \gamma_k \Delta f p_{t-k} + \sum_{k=0}^{N_y} \theta_k y_{t-k} + v \tag{20}$$

Comparing with the original model (equation (15)), equation (20) added one more controlling variable y_t, the growth rate of Finland's domestic demand. Finland's monthly domestic demand is usually described by the trend indicator of output, which shows the fluctuation of monthly GDP. This study plans to build the variable of the growth rate of Finland's domestic demand from three different methods: ① The cyclical component of the logarithmic trend indicator of Finland's output, obtained from Hodrick-Prescott Filter with the parameter lambda equal to 129600[48]; ② The first-differenced logarithmic trend indicator of Finland's output; ③ The year-on-year difference of the logarithmic trend indicator of Finland's output. Correspondingly, the ERPT $\sum_{k=0}^{N_e} \beta_k$ on Finnish import prices will be reported with both the original model and the model with the controlling variable formed by different method. When we run the regression, $N_e = N_{fp} = N_y \neq N_p$ is allowed.

[48] The determination of the parameter lambda in HP Filter is based on: Ravn, M. O., & Uhlig, H. (2002). On adjusting the Hodrick-Prescott filter for the frequency of observations. *Review of economics and statistics*, *84*(2), 371-376.

5. Data

The variables needed for the empirical model are based on four groups of aggregated-level data: the aggregated foreign PPI, the aggregated foreign Effective PPI, the aggregated foreign exchange rate and the Finnish Import Index. Except the Finnish Import Index is directly provided from Statistics Finland, the other aggregated-level data are all generated from elementary data: the annual import value of Finland's trade partners, the monthly individual PPI and the monthly nominal foreign exchange rate of the 15 selected Finland's trade partners. The data sources, along with the relation between the elementary and the aggregated data, are briefly illustrated in Figure 3. This part mainly focuses on describing both the elementary and the aggregated data.

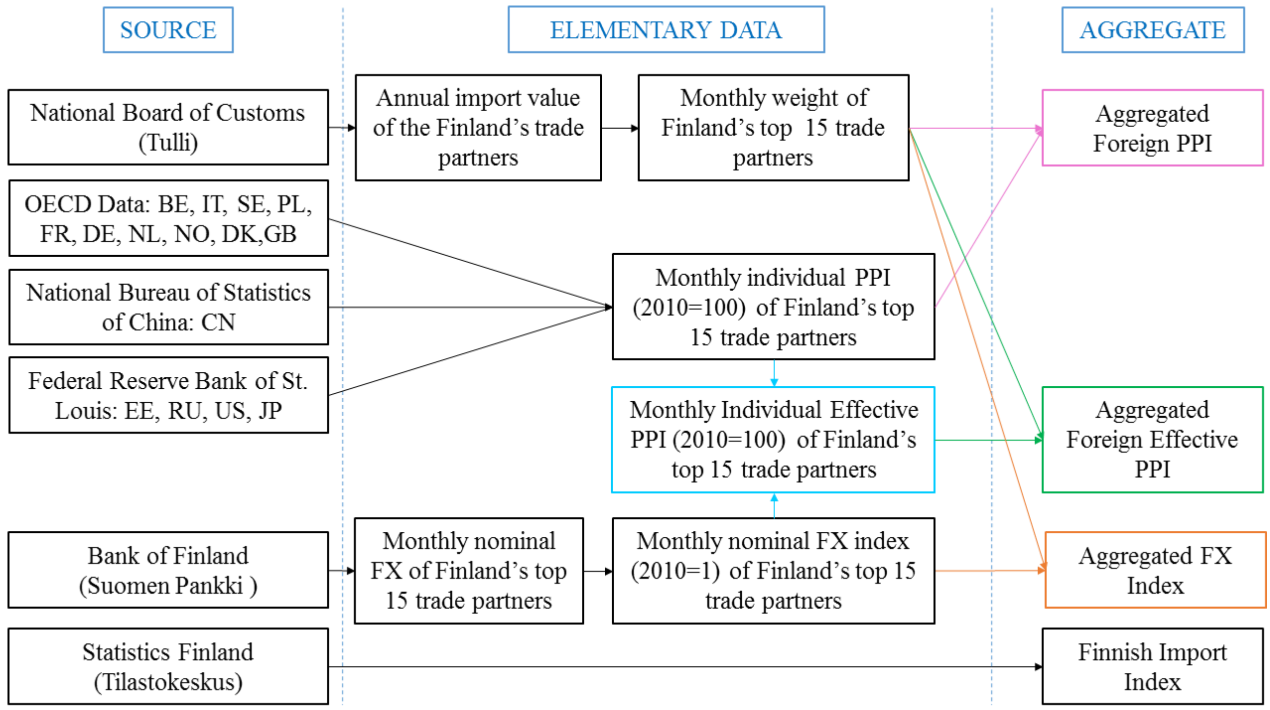

Figure 3 Data Structure

5.1 Elementary Data

5.1.1 Annual Import Value

The annual import value of Finland's trade partners is used to select and sort the countries, of which the import value to Finland ranks the top 15; it is also used for deriving the weight of each selected country to yield the aggregated-level data, the aggregated foreign PPI, the aggregated foreign Effective PPI and the aggregated foreign exchange rate index. The data of the annual import value is collected by the National Board of Customs (Tulli) in Finland. The series are available from 2001 to 2017.

Based on the total import value in the 17 years, 15 countries with the highest import value to Finland are selected as the interested trade partners in this study: Germany, Sweden, Russia, the Netherlands, France, Denmark, Estonia, Belgium, the United Kingdom, Poland, Italy, Norway, the United States, China and Japan (Order is based on the total import value in 2017, from the highest to the lowest).

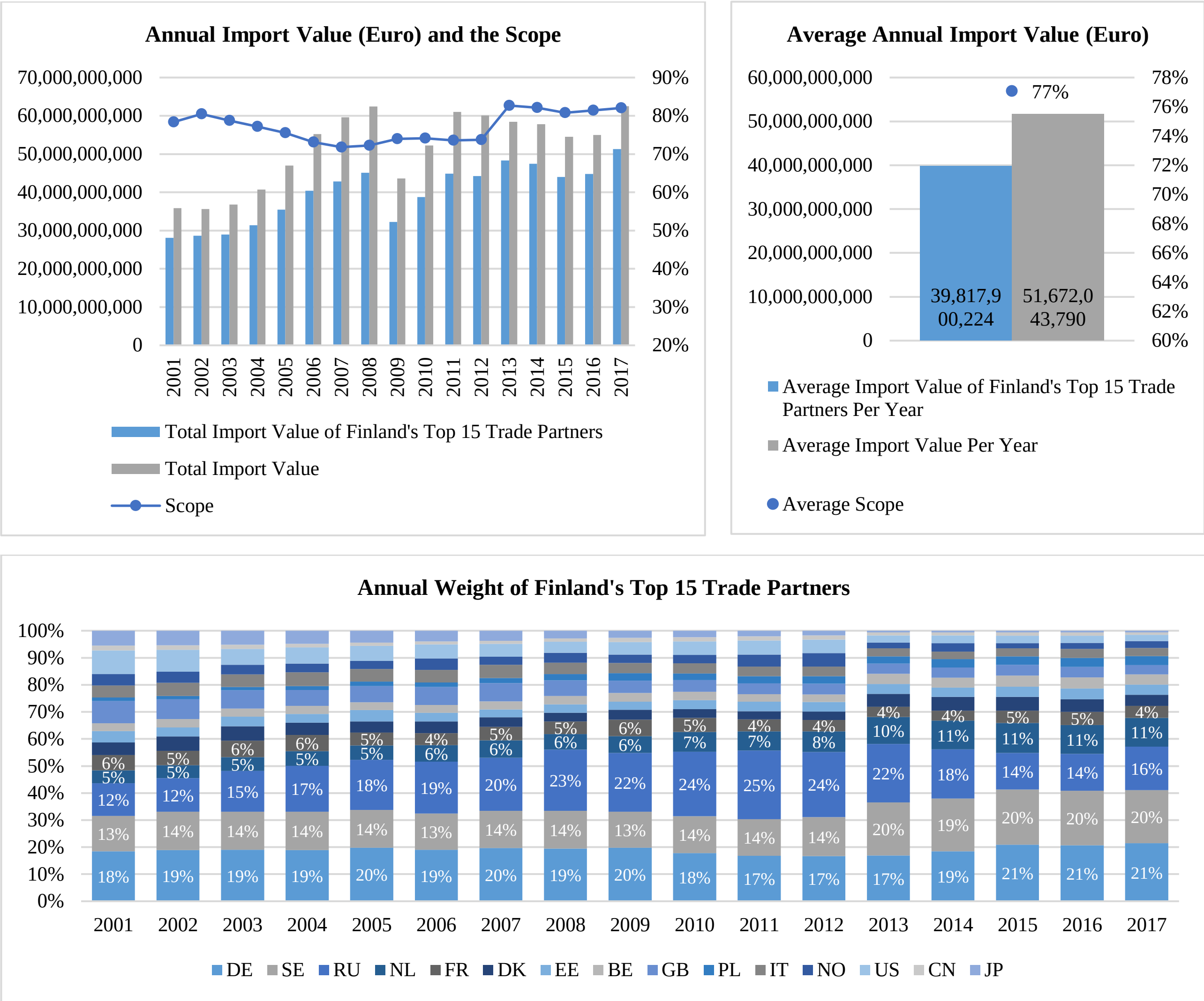

Figure 4 Annual Import Value, Scope and Weight of Finland's Top 15 Trade Partners

Figure 4 illustrates the annual import value and the scope of Finland's top 15 trade partners, as well as the annual weight calculated via equation (19). The average annual import value of the whole Finland is 51,672,043,790 Euro from 2001 to 2017, and the average annual import value of the whole 15 selected countries are 39,817,900,224 Euro, covering 77% of the average annual import value of the whole Finland. Precisely, the scope in each year varies from 72% to 83%. Within the 15 selected countries, Germany, Sweden, Russia, the Netherlands and France contribute around

60% of the total annual import value, where the shares (weights) of Germany and Sweden have increased in the past 17 years, while the share of Russia has decreased since 2014. The decreasing weight of Russia can ascribe to the financial crisis that resulted from the sharp devaluation of Ruble from 2014 to 2015.

5.1.2 Monthly Individual Producer Price Index

Campa and Goldberg (2005) used Consumer Price Index (CPI) to measure the marginal cost[49]. However, CPI might not be an idea indicator for the price development of the exporter's marginal cost, because the consumer prices has been added the wholesale trade margin and the retail trade margin on the producer price. Gagnon and Ihrig (2001)[50] also argued that monetary authorities' policy may limit the responsiveness of CPI. In this study, the measurement for the foreign competing prices (exporter's marginal cost) will employ the aggregated Producer Price Index (PPI).

Data on monthly individual Producer Price Index (2010=100) of the 15 selected Finland's trade partners participate both the aggregates of the foreign PPI and the foreign Effective PPI. As the original reference years diverse from different sources, the data of the monthly individual PPI serving for the aggregates have been rescaled with the year 2010 as the reference period[51]. All the PPI data are not seasonally adjusted. Figure 5 illustrates the individual PPI of the 15 selected Finland's trade partners into four groups.

The data on individual PPI are collected from three sources. First, the data of the monthly PPI from 2001 to 2017 of Belgium, Italy, Sweden, Poland, France, Germany, Norway, Denmark and the United Kingdom are collected from the database of the Organization for Economic Co-operation and Development (OECD)[52]. The reference period of the original monthly PPI of the nine countries is the year 2015. Second, the data of the monthly PPI from 2001 to 2017 of Estonia, Russia, the United States and Japan are collected from the database of the Economic Research Division of the

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[49] Campa, J. M., Goldberg, L. S., & González-Mínguez, J. M. (2005). *Exchange-rate pass-through to import prices in the Euro area* (No. w11632). National Bureau of Economic Research.
[50] Gagnon, J. E., & Ihrig, J. (2004). Monetary policy and exchange rate pass-through. *International Journal of Finance & Economics*, *9*(4), 315-338.
[51] The method to rescale the individual PPI is to divide each observation by the average value of the reference year 2010.
[52] The Producer Price Index database of the OEDC: https://data.oecd.org/price/producer-price-indices-ppi.htm

Federal Reserve Bank of St. Louis[53]. The reference periods of the original monthly PPI of Estonia, Russia and Japan are the same year 2015, and the reference period of the original monthly PPI of the United States is the year 1982. Third, the data of the monthly PPI from 2001 to 2017 of China are collected from the National Bureau of Statistics of China[54]. The data of the monthly PPI of China serving for the aggregates are calculated from two original series: Year-on-Year PPI (the same month last year =100) from October 1996 to December 2018 and Month-on-Month PPI (last month = 100) from January 2011 to December 2018. The trend of the calculated monthly PPI aligns with the annual PPI published by the Federal Reserve Bank of St. Louis.

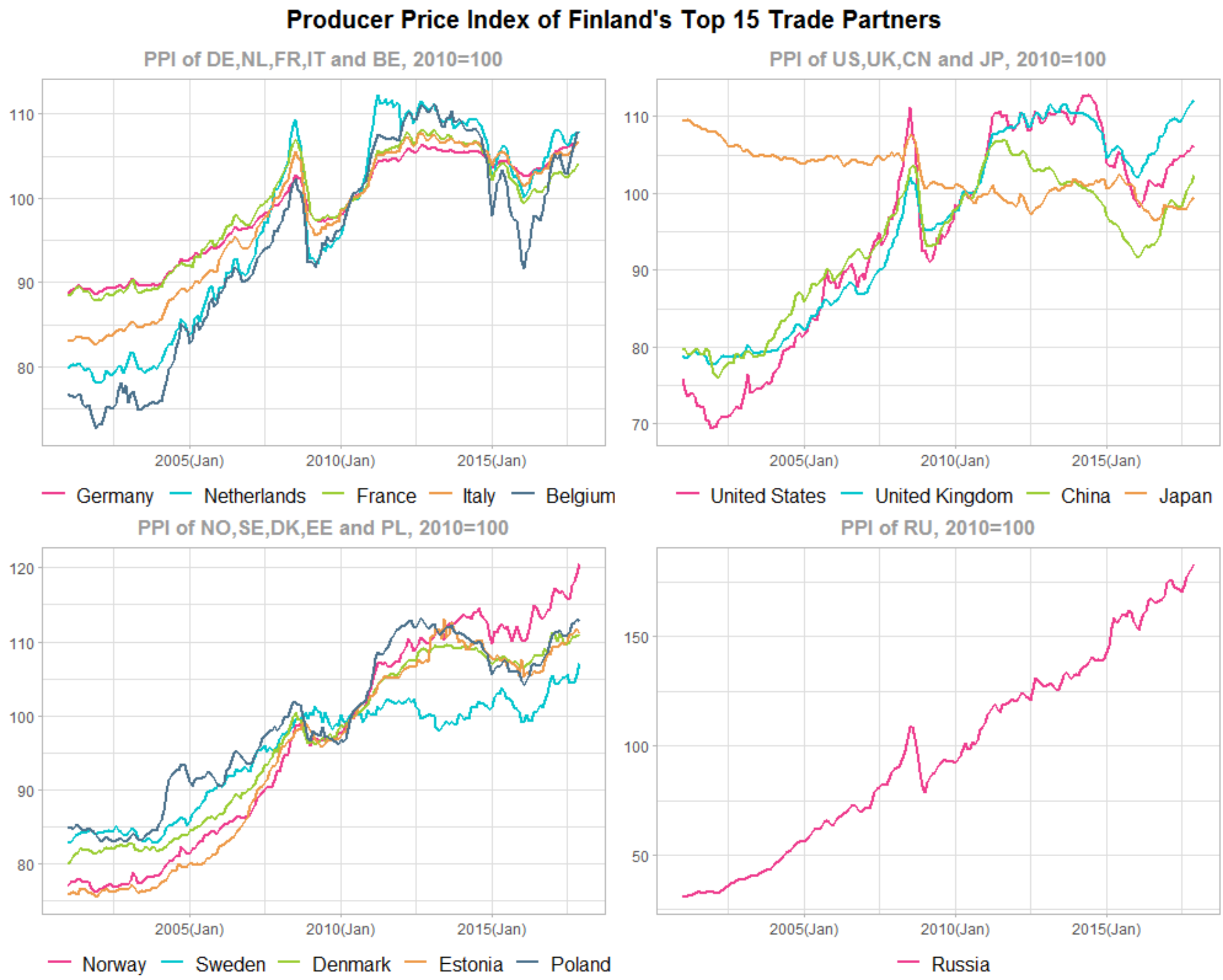

Figure 5 Producer Price Index of Finland's Top 15 Trade Partners

[53] Economic Research Division of Federal Reserve Bank of St. Louis: https://fred.stlouisfed.org
[54] National Bureau of Statistics of China: http://data.stats.gov.cn/english/easyquery.htm?cn=A01

5.1.3 Monthly Nominal Foreign Exchange Rate

The monthly nominal foreign exchange rate is collected from the Bank of Finland (Suomen Pankki)[55]. The exchange rates on the Bank of Finland are euro reference rates published by the European Central Bank (ECB), based on the regular concertation procedure between national central banks and held daily at 3:15 p.m. Finnish time[56]. The monthly nominal foreign exchange rates used for the aggregates have been converted into the form of Euro (the importer's currency) per unit of the exporter's (the 15 selected countries') currency.

The data of the monthly nominal foreign exchange rate and the monthly individual PPI data generate the monthly individual Effective PPI, which denotes the development of the producer prices of Finland's top 15 trade partners in Euro, the importer's currency. Figure 12 in the Appendix illustrates the difference between the individual PPI and Effective PPI. The curves of PPI and the Effective PPI coincide in the country whose currency is Euro.

5.2 Aggregated Data

As Figure 3 shows, combined with the monthly weight of each observation, the monthly individual PPI, Effective PPI and the nominal FX Index generate the aggregated foreign PPI, the aggregated foreign Effective PPI and the Aggregated FX Index. The aggregating methods of the three indices refer to equation (16), equation (17) and equation (18) in Table 2. It is also necessary to point it out that equation (16), (17) and (18) have logged the aggregated-level indices, while Figure 6 depicts Finnish Import Index and the three manually aggregated indices without logarithm. Moreover, the logarithmic Finnish Import Index, aggregated foreign PPI, aggregated foreign Effective PPI and the aggregated FX Index correspond to p_t, fp_t , fp_t^E and e_t respectively in the regression equation (15) and (20). Besides the data for the four variables, we plan to discuss and visualized data of the controlling variable y_t, the growth rate of Finland's domestic demand, in the part of the Robustness Check. Here we would just mention the monthly unadjusted data on trend indicator of Finland's output is also collected from Statistics Finland.

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[55] Database of exchange rate, monthly average, in the Bank of Finalnd: https://www.suomenpankki.fi/en/Statistics/exchange-rates/tables/valuuttakurssit_taulukot_en/valuuttakurssit_long_en/

[56] The description of the exchange rates in the Bank of Finland: https://www.suomenpankki.fi/en/Statistics/exchange-rates/description/

The upper chart in Figure 6 shows the Finnish Import Index, the aggregated foreign PPI and foreign Effective PPI scaled with the same reference period, 2010=100. Finnish Import Index represents the development of Finnish import prices; the aggregated foreign PPI and the foreign Effective PPI, as two alternative indices, display the development of the average marginal cost or the average competing prices of Finland's top 15 trade partners. Based on the movement of the three indices, we would conclude that the development of the import prices and foreign marginal cost follows almost the same fluctuation and an upward trend. The lower chart in Figure 6 illustrates the movement of the aggregated foreign exchange rate index. Since the aggregated-level index is built from the monthly nominal exchange rate in the form of Euro (importer's currency) per unit of the exporter's currency, the downward trend of the aggregated index reveals that Euro has been depreciated from 2001 to 2017. Correspondingly, as it is observed that the Finnish import prices have increased from 2001 to 2017, it meets the intuition that the deprecation of Euro leads the increase of import prices, and this research is exactly aimed at quantifying the linkage between these two movements.

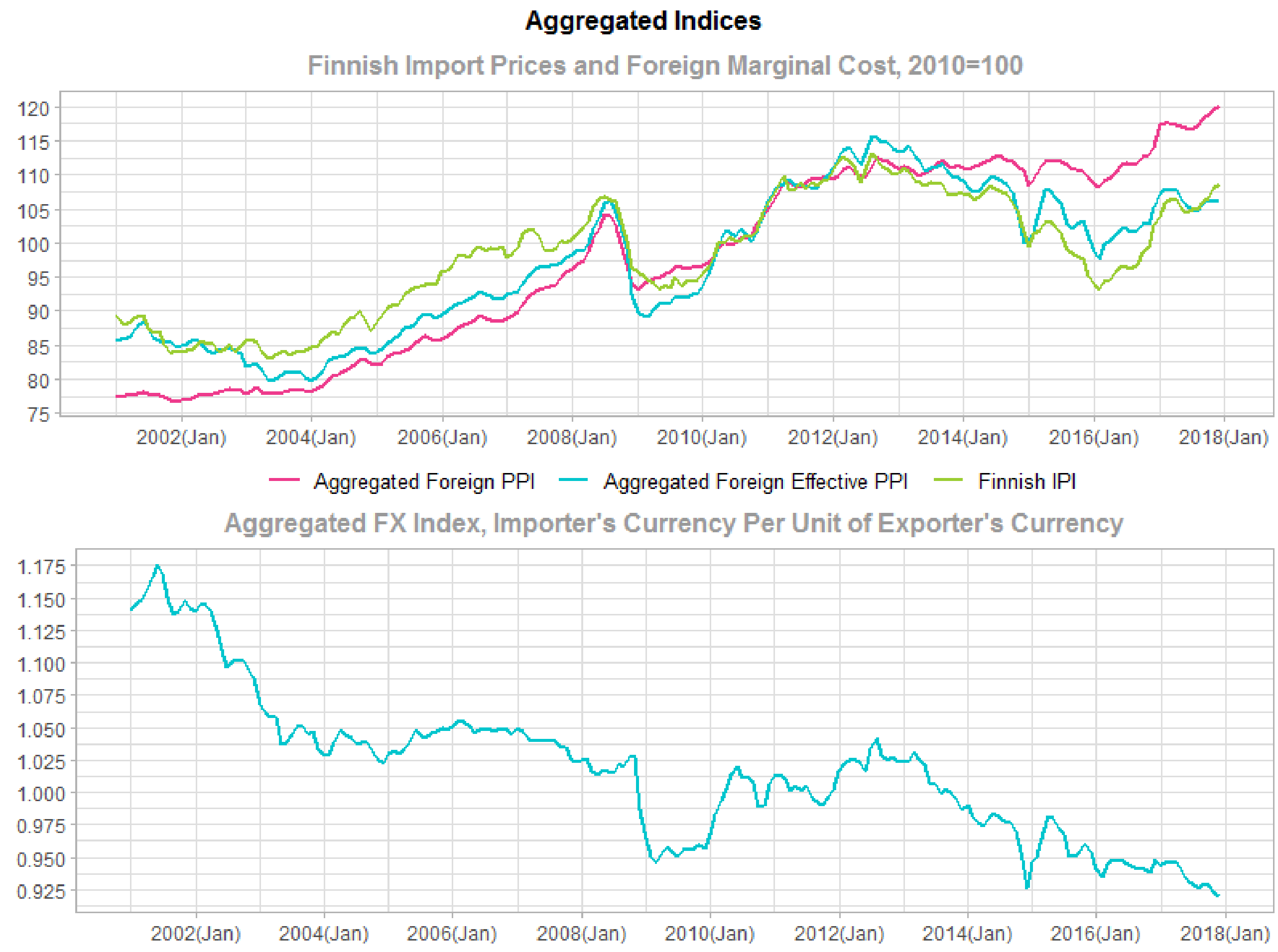


Figure 6 Aggregated PPI, Aggregated Effective PPI, Finnish Import Index and Aggregated FX Index

6. Analysis and Evidence

6.1 Invalidity of the Law of One Price

The analysis of the ERPT starts with testing whether the Low of One Price holds. Two steps of the LOP verification are taken into consideration: first, test the stationarity of the logarithmic Finnish import prices p_t, aggregated exchange rate index e_t and the aggregated foreign (Effective) PPI $fp_t^{(E)}$; Second, test the stationarity of $\epsilon_t = p_t - e_t - fp_t$ for the cointegration of the three variables. It is necessary to point out that $\epsilon_t^E = p_t - fp_t^E$ will be applied for testing LOP, if the logarithmic foreign Effective PPI is considered as the foreign marginal cost, because fp_t^E has already included the exchange rate index during the aggregate process. Before testing the validity of LOP and the ERPT estimation, the data preparation requires removing the seasonality of the Finnish Import Index and the aggregated foreign (Effective) PPI. The turquoise lines in Figure 13 in Appendix show the development of the indices whose seasonality has been manually removed. A precise description of the seasonality of the aggregate-level indices can be found in Appendix Figure 14 Decomposition of the Unadjusted and Adjusted Indices.

In practice, the Augmented Dickey-Fuller test shows that none of the four process p_t, e_t, fp_t and fp_t^E is a stationary process, including either a drift or a trend. Most tests cannot reject the null hypothesis of a unit root even at the 10% significance level. Meanwhile, neither $\epsilon_t = p_t - e_t - fp_t$ nor $\epsilon_t^E = p_t - fp_t^E$ is a stationary process. We would conclude that the Law of One Price does not hold in long term between Finland and its trade partners, and the Finnish import prices shall not fully respond to the exchange rate in long term. The values of test-statistics and the critical values of each ADF test are reported in Table 4.

Since we have proved that LOP does not hold and ERPT shall not equal to 1 in long term, then we plan to use the first-differenced logarithmic variable to fit the model, the equation (15). To ensure the residual of the model is a stationary process, we would firstly check whether the first-differenced logarithmic Finnish Import Index, aggregated FX Index and the aggregated foreign PPI are stationary processes. The results of the ADF test are organized in Table 5, where all the processes participating the regression model in equation (15) are stationary, by rejecting the null hypothesis of a unit root at the 1% significant level. The movements of the first-differenced variables are plotted as Figure 15 in the Appendix, where the pass-through we interested in is the linkage between the movements of the first-differenced logarithmic Finnish Import Index and FX Index.

Logarithmic variables	Type of ADF test	Value of test-statistics	1%	5%	10%	Conclusions
IPI (p_t)	Drift	-1.6708	-3.46	-2.88	-2.57	Nonstationary. Cannot reject the null hypothesis at the 10% significance level in both tests.
	Trend	-2.11	-3.99	-3.43	-3.13	
FX Index (e_t)	Drift	-2.1628	-3.46	-2.88	-2.57	Nonstationary. Cannot reject the null hypothesis of a unit root at the 10% and 5% significance level in the test with a drift and with a trend respectively.
	Trend	-3.376	-3.99	-3.43	-3.13	
PPI (fp_t)	Drift	-0.7367	-3.46	-2.88	-2.57	Nonstationary. Cannot reject the null hypothesis at the 10% significance level in both tests.
	Trend	-2.1634	-3.99	-3.43	-3.13	
Effective PPI (fp_t^E)	Drift	-1.1417	-3.46	-2.88	-2.57	Nonstationary. Cannot reject the null hypothesis at the 10% significance level in both tests.
	Trend	-2.2467	-3.99	-3.43	-3.13	
$\epsilon_t = p_t - e_t - fp_t$	Drift	-1.8001	-3.46	-2.88	-2.57	Nonstationary. Cannot reject the null hypothesis of a unit root at the 10% and 5% significance level in the test with a drift and with a trend respectively. The Law of One Price doesn't hold.
	Trend	-3.2639	-3.99	-3.43	-3.13	
$\epsilon_t^E = p_t - fp_t^E$	Drift	-1.8289	-3.46	-2.88	-2.57	Nonstationary. Cannot reject the null hypothesis of a unit root at the 10% significance level. The Law of One Price doesn't hold.
	Trend	-2.906	-3.99	-3.43	-3.13	

Table 4 Results of ADF Test for LOP Reported from R

First-differenced logged variables	Type of ADF test	Value of test-statistics	1%	5%	10%	Conclusions
IPI (Δp_t)	Drift	-6.8749	-3.46	-2.88	-2.57	Stationary. Reject the null hypothesis at the 1% significance level in both tests.
	Trend	-6.8564	-3.99	-3.43	-3.13	
FX Index (Δe_t)	Drift	-8.4856	-3.46	-2.88	-2.57	Stationary. Reject the null hypothesis at the 1% significance level in both tests.
	Trend	-8.4775	-3.99	-3.43	-3.13	
PPI (Δfp_t)	Drift	-7.4302	-3.46	-2.88	-2.57	Stationary. Reject the null hypothesis at the 1% significance level in both tests.
	Trend	-7.4128	-3.99	-3.43	-3.13	

Table 5 Results of ADF Test for the First-Differenced Variables

6.2 Exchange Rate Pass-Through Estimation

Since the ADF test has confirmed the stationarity of the variables Δp_t, Δe_t and Δfp_t, we would further fit the model and report the coefficient $\sum_{k=0}^{N_e} \beta_k$ of the FX Index as the ERPT on Finnish import prices, beginning with selecting the N_p^* as the lag length N_p for the Finnish Import Index Δp_t by Akaike Information Criterion (AIC). Once we have controlled the lag length N_p, we will fit the model with the lag length of the first-differenced logarithmic FX Index (N_e) and foreign PPI (N_{fp})

selected from 11 to 0. Then based on the first significant coefficient β_k at the k^{th} lag, we will finally conclude the accumulated effect of pass-through within k+1 months as the ERPT in the long term, giving both the confidence interval and the significance level corresponding to the null and alternative hypotheses.

In practice, AIC selects 1 lag for the Finnish Import Index[57]. By controlling $N_p = N_p^* = 1$, each coefficient β_k at the kth lag and the accumulated effect of the pass-through $\sum_{k=0}^{N_e} \beta_k$ is reported in Table 6 below, whose individual significance level here corresponds to the null hypothesis. The significance level of both the null and alternative hypothesis of the accumulated pass-through will be reported separately in Table 7.

AIC selected 1 lag for Δp_{t-k}, $N_p = N_p^* = 1$: $\Delta p_t = c + \sum_{k=1}^{N_p=1} \alpha_k \Delta p_{t-k} + \sum_{k=0}^{N_e} \beta_k \Delta e_{t-k} + \sum_{k=0}^{N_{fp}} \gamma_k \Delta fp_{t-k} + v$													
Lags for Δe_t and Δfp_t	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}	$\sum_{k=0}^{N_e} \beta_k$
$N_e = N_{fp} = 0$	0.363*** (0.071)												0.363 (0.071)
$N_e = N_{fp} = 1$	0.344*** (0.076)	0.127 (0.078)											0.471 (0.096)
$N_e = N_{fp} = 2$	0.367*** (0.076)	0.065 (0.083)	0.113 (0.074)										0.545 (0.112)
$N_e = N_{fp} = 3$	0.377*** (0.078)	0.077 (0.084)	0.083 (0.080)	0.089 (0.075)									0.626 (0.134)
$N_e = N_{fp} = 4$	0.372*** (0.078)	0.085 (0.085)	0.108 (0.080)	0.013 (0.080)	0.129. (0.074)								0.707 (0.152)
$N_e = N_{fp} = 5$	0.367*** (0.079)	0.078 (0.085)	0.087 (0.081)	0.009 (0.081)	0.143. (0.080)	-0.097 (0.075)							0.587 (0.172)
$N_e = N_{fp} = 6$	0.363*** (0.079)	0.093 (0.086)	0.097 (0.082)	0.012 (0.082)	0.147. (0.081)	-0.091 (0.081)	-0.013 (0.076)						0.606 (0.187)
$N_e = N_{fp} = 7$	0.361*** (0.080)	0.091 (0.087)	0.092 (0.083)	0.015 (0.083)	0.156. (0.082)	-0.098 (0.083)	0.000 (0.082)	0.016 (0.076)					0.634 (0.203)
$N_e = N_{fp} = 8$	0.362*** (0.080)	0.099 (0.088)	0.097 (0.084)	0.008 (0.084)	0.148. (0.083)	-0.117 (0.084)	0.003 (0.083)	0.006 (0.082)	-0.051 (0.076)				0.555 (0.216)
$N_e = N_{fp} = 9$	0.372*** (0.080)	0.103 (0.088)	0.074 (0.084)	0.017 (0.084)	0.158. (0.083)	-0.110 (0.084)	-0.008 (0.085)	0.006 (0.083)	-0.033 (0.082)	-0.091 (0.077)			0.488 (0.224)
$N_e = N_{fp} = 10$	0.389*** (0.081)	0.107 (0.088)	0.076 (0.084)	0.008 (0.085)	0.156. (0.084)	-0.089 (0.085)	-0.009 (0.085)	0.011 (0.084)	-0.026 (0.083)	-0.100 (0.083)	0.010 (0.076)		0.531 (0.233)
$N_e = N_{fp} = 11$	0.396*** (0.082)	0.097 (0.090)	0.076 (0.085)	0.004 (0.085)	0.176* (0.085)	-0.090 (0.086)	-0.018 (0.086)	0.001 (0.084)	-0.044 (0.084)	-0.095 (0.084)	-0.013 (0.083)	-0.009 (0.077)	0.480 (0.243)
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1													

Table 6 ERPT Reported from the Model without the Controlling Variable

57 Reported from R: AIC=-1285.99 AICc=-1285.93 BIC=-1279.36

Table 6 shows the initial estimates of the short-term ERPT and the accumulated ERPT effect in long term. There are two aspects that we would address in the analysis: ① Based on the significance level of the coefficient β_k at each lag, we are able to determine the maximum lag length for the "long-term" ERPT. ② Besides the standard error of the individual estimate at each lag, we are also able to find out the standard error and obtain the confidence interval of the sum of the coefficient $\sum_{k=0}^{N_e} \beta_k$.The determination of the maximum lag length of the "long-term" ERPT and the calculation of the standard error of the accumulated pass-through effect will be elaborated as follows.

(i) **Maximum lag length of the "long-term"**: As it is displayed in Table 6, the coefficient β_k which first becomes significantly different zero at 5% or 10% significance level is always located at the 4$^{\text{th}}$ lag, when we start the test from whichever lag length (larger than 4) of the first-differenced logarithmic FX Index and PPI. Therefore, we define the "long term" as 4 months a head of the current period, and thus the long-term ERPT $\sum_{k=0}^{4} \beta_k$ can be understand as the accumulated pass-through effect within 5 months.

(ii) **Standard error of long-term ERPT**: The figure in the bracket in each cell in Table 6 reports the standard error of the corresponding coefficient, which tells us how far the average estimated pass-through at each lag could deviate from the actual value. The individual standard error is reported directly from R, while the standard error of the sum of the coefficients $\sum_{k=0}^{N_e} \beta_k$, as the green figures in the last column, is computed via equation (21) to equation (24).

a) We build X as the regressor matrix of the model, whose dimension is n×(2k+4). n is the observation of each vector, and k is the maximum lag length that we selected for the variable of FX Index and PPI. β is the coefficient matrix with the dimension of (2k+4) ×1.

$$\Delta p_t = X\beta + v \tag{21}$$

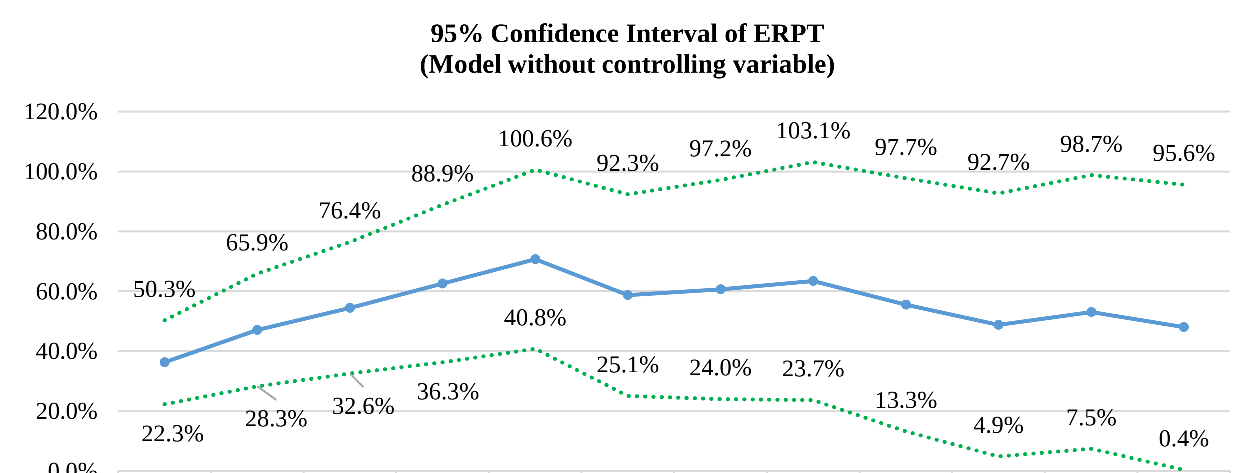
b) The variation of the sum of all the coefficient (including the estimate of the intercept) is calculated by the equation (22), where δ is the standard error of the model's residual. The standard error of the model's residual can be easily found from the summary of the regression summary in R.

$$Var(\hat{\beta}) = \delta^2(X^T X)^{-1} \tag{22}$$

c) If we merely want to know the standard error of the sum of specific coefficients, we need add the a vector w with the dimension of $(2k+4)\times1$to weight the estimate of each regressor. For example, in the case where we select the 2-lag length as the maximum lag length of the variable of FX Index and PPI, the dimension of the regressor matrix X will be $n\times8$, and the weight to each regression shall be $w = [0 \quad 0 \quad 1 \quad 1 \quad 1 \quad 0 \quad 0 \quad 0]'$, where the elements that equal to 1 give the corresponding weight to the estimate of Δe_t, Δe_{t-1} and Δe_{t-2}. Equation (23) shows the approach to calculate the variation of the weighted estimate, and then the standard error can be easily obtained via equation (24).

$$Var(w^T\hat{\beta}) = w^T\delta^2(X^T X)^{-1}w \tag{23}$$

$$SE = Var(w^T\hat{\beta})^{1/2} = [w^T\delta^2(X^T X)^{-1}w]^{1/2} \tag{24}$$



	0	1	2	3	4	5	6	7	8	9	10	11
ERPT	36.3%	47.1%	54.5%	62.6%	70.7%	58.7%	60.6%	63.4%	55.5%	48.8%	53.1%	48.0%
CImax	50.3%	65.9%	76.4%	88.9%	100.6%	92.3%	97.2%	103.1%	97.7%	92.7%	98.7%	95.6%
CImix	22.3%	28.3%	32.6%	36.3%	40.8%	25.1%	24.0%	23.7%	13.3%	4.9%	7.5%	0.4%

Figure 7 95% Confidence Interval of the ERPT in the Model without Controlling Variable

Once we have computed the standard error of the estimated long-term EPRT on Finnish Import prices, we are able to calculate the confidence interval of our estimates. Figure 7 plots the 95% confidence interval of the ERPT, where the green dashed curves outline the maximum and the minimum value of the confidence interval. The average estimate of ERPT with different maximum lag length is believed to be located within the area between the maximum and the minimum values with 95% probability. Based on the analysis with the model without any controlling variable, we would conclude the initial estimate of the short-term ERPT on Finnish import prices is 36.3%, and the long-term ERPT on Finnish import prices is 70.7%. Meanwhile, Table 7 below give the significance level of each accumulated pass-through estimate: both estimates of the short-term and the long-term ERPT are significantly different from 0 at the 1% significance level, while the alternative hypothesis is rejected at the 1% significance level for the short-term ERPT and at the 10% significance level for the long-term ERPT.

Significance Level of the Accumulated Pass-Through Effect

ERPT	β_0	$\sum_{k=0}^{1}\beta_k$	$\sum_{k=0}^{2}\beta_k$	$\sum_{k=0}^{3}\beta_k$	$\sum_{k=0}^{4}\beta_k$	$\sum_{k=0}^{5}\beta_k$	$\sum_{k=0}^{6}\beta_k$	$\sum_{k=0}^{7}\beta_k$	$\sum_{k=0}^{8}\beta_k$	$\sum_{k=0}^{9}\beta_k$	$\sum_{k=0}^{10}\beta_k$	$\sum_{k=0}^{11}\beta_k$
Estimate	0.363	0.471	0.545	0.626	0.707	0.587	0.606	0.634	0.555	0.488	0.531	0.480
H_0	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.002 ***	0.002 **	0.004 **	0.016 *	0.041 *	0.033 *	0.065 .
H_1	0.000 ***	0.000 ***	0.000 ***	0.007 **	0.067 .	0.025 *	0.047 *	0.089 .	0.053 .	0.031 *	0.060 .	0.046 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 7 p-value Reported from F Test in R, for the Model without Controlling Variable

6.3 Model Diagnostics

6.3.1 Robustness Check-up

The estimates of ERPT we have obtained above are based on the model without any controlling variable. To check the robustness of the estimates, we will add one controlling variable, the growth rate of Finnish domestic demand, to the original model. Equation (20) will be employed as the regression equation for the robustness check-up. The controlling variable is built from the monthly trend indicator of Finland's output. After removing the seasonality of the trend indicator of output, we construct the variable of the growth rate of Finland's domestic demand by three different methods: ① The cyclical component of the logarithmic trend indicator of Finland's output, obtained from Hodrick-Prescott Filter; ② The first-differenced logarithmic trend indicator of Finland's output; ③ The year-on-year difference of the logarithmic trend indicator of Finland's output. The Hodrick-Prescott Filter and the process of the controlling variable formed with different method are plotted as Figure 16 and Figure 17 in the Appendix.

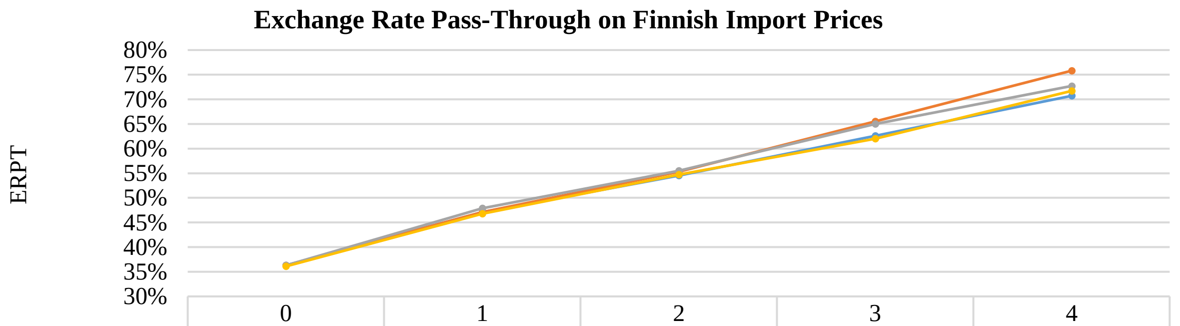
In practice, AIC selected 1-lag length for the Finnish Import Index, and we fit the model by reducing the lag length of FX Index, PPI and the Finnish output, from $N_e = N_{fp} = N_y = 11$ to $N_e = N_{fp} = N_y = 0$. Table 8 below gives an overview of the ERPT with its significance level corresponding to both the null and the alternative, estimated from the model with the controlling variable formed by the three methods mentioned above. The detail of the ERPT at each lag, along with its standard error and the significance level, is reported in Table 11, Table 12 and Table 13 in the Appendix for the model with the different controlling variable respectively. If we compare the ERPT and its significant level between the model with and without the control of Finland's domestic demand, the estimates are similar. This is our first evidence to ensure the estimate of ERPT is robust.

ERPT with different lag length		β_0	$\sum_{k=0}^{1}\beta_k$	$\sum_{k=0}^{2}\beta_k$	$\sum_{k=0}^{3}\beta_k$	$\sum_{k=0}^{4}\beta_k$	$\sum_{k=0}^{5}\beta_k$	$\sum_{k=0}^{6}\beta_k$	$\sum_{k=0}^{7}\beta_k$	$\sum_{k=0}^{8}\beta_k$	$\sum_{k=0}^{9}\beta_k$	$\sum_{k=0}^{10}\beta_k$	$\sum_{k=0}^{11}\beta_k$
Cyclical Component (As controlling variable)	**ERPT**	36.3%	47.1%	55.3%	65.5%	75.8%	56.4%	57.7%	57.8%	50.4%	45.1%	50.2%	35.5%
	H_0	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.004 **	0.007 **	0.013 *	0.044 *	0.083 .	0.070 .	0.222
	H_1	0.000 ***	0.000 ***	0.000 ***	0.017 *	0.154	0.027 *	0.046 *	0.069 .	0.048 *	0.036 *	0.072 .	0.028 *
First Difference (As controlling variable)	**ERPT**	36.3%	47.9%	55.5%	65.0%	72.7%	59.5%	58.7%	59.9%	54.4%	47.9%	54.8%	46.7%
	H_0	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.002 **	0.004 **	0.007 **	0.021 *	0.048 *	0.031 *	0.080 .
	H_1	0.000 ***	0.000 ***	0.000 ***	0.015 *	0.096 .	0.033 *	0.043 *	0.068 .	0.052 .	0.032 *	0.075 .	0.046 *
Y.O.Y Growth Rate (As controlling variable)	**ERPT**	36.1%	46.8%	54.7%	62.0%	71.7%	57.3%	60.8%	60.8%	54.3%	48.7%	58.9%	46.2%
	H_0	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.004 **	0.005 **	0.010 *	0.033 *	0.071 .	0.041 *	0.130
	H_1	0.000 ***	0.000 ***	0.000 ***	0.008 **	0.092 .	0.031 *	0.069 .	0.096 .	0.073 .	0.058 .	0.151	0.077 .

Table 8 ERPT and the p-value Reported from F Test in R, for the Model with Controlling Variables Formed by Different Method

Besides the robustness of the estimate, the difference of the ERPT estimated from the original model and the model with the controlling variable can also tell us how Finland's domestic demand influences the ERPT on Finnish import prices. Intuitively, after controlling the domestic demand, the estimate of ERPT on Finnish import prices shall increase. The reason behind is that the high demand in Finland's domestic market likely incentives the exporters to increase the markup when pricing to Finland’s market, which causes the Finnish import prices to increase. However, the increase of Finnish import prices in this case is independent of the fluctuation of exchange rate, and the pricing behaviour of the exporter has in fact deviates the movement of Finnish import price from that of the exchange rate. In brief, the high domestic demand likely reduces the ERPT by changing the exporters’ pricing behaviour. Hence, if we are able to control the domestic demand, the ERPT on Finnish import prices is expected to increase.

Since we have defined the “long term” as the 4-lag length ahead of the current month, we are only interested in the change of ERPT at the current month (short term) and the 5-month accumulated pass-through effect (long term). Figure 8 below shows the estimates from the model with and without the controlling variable, where the blue curve represents the ERPT estimated from the original model. After adding the controlling variable, the ERPT indeed has increased around 1 to 5 percentage points when 2-lag to 4-lag length for the FX Index is selected, although in short term, e.g. 0 or 1-lag length, ERPT does not influenced by controlling the domestic demand.



	0	1	2	3	4
No control	36.3%	47.1%	54.5%	62.6%	70.7%
Cyclical component	36.3%	47.1%	55.3%	65.5%	75.8%
First difference	36.3%	47.9%	55.5%	65.0%	72.7%
Y.O.Y growth rate	36.1%	46.8%	54.7%	62.0%	71.7%

Figure 8 ERPT Estimated from the Model with and without the Controlling Variable

In addition, Table 9 in the next page shows the significance level of the estimate of the controlling variable formed by different method. Except θ_4 corresponding to the first-differenced logarithmic Finland’s output at the 4th which is significantly different from 0 at the 5% significance level, none of the estimate from the defined short term to the long term is significantly different from 0. This result aligns with Figure 8, which depicts that the Finland’s domestic demand has little impact on the short-term pass-through, while it likely reduces the long-term ERPT by 1 to 5 percentage points.

Cyclical Component					First Difference					Year-on-Year Growth Rate				
θ_0	θ_1	θ_2	θ_3	θ_4	θ_0	θ_1	θ_2	θ_3	θ_4	θ_0	θ_1	θ_2	θ_3	θ_4
0.787	0.948	0.5596	0.406	0.2596	0.895	0.755	0.655	0.575	0.5793	0.373	0.858	0.6485	0.728	0.6964
	0.959	0.6027	0.522	0.2665		0.533	0.4686	0.404	0.227		0.173	0.3568	0.372	0.6181
		0.3634	0.353	0.5242			0.8853	0.791	0.7523			0.7071	0.668	0.9613
			0.672	0.6224				0.874	0.2388				0.801	0.531
				0.5379					0.0164*					0.3708

Table 9 p-value of the Estimate of Finland's Output (the Controlling Variable)

If we plot the estimates of the ERPT estimate in the model with and without the controlling variable, along with the 95% confidence interval yielded from the original model without any controlling variable, in the same figure as the upper-left one in Figure 9 shows below, all the estimates are located within in the confidence interval, regardless of the controlling method. Moreover, the 95% confidence interval of the model with different controlling method shows similarity in both the maximum and the minimum value, especially for the first 4 lags which we defined as from the short term to the long term. Hence, we would conclude that the estimated ERPT from the model with the controlling variable formed by different mothed has no significant difference from the ERPT estimated by our original model without any controlling variable.

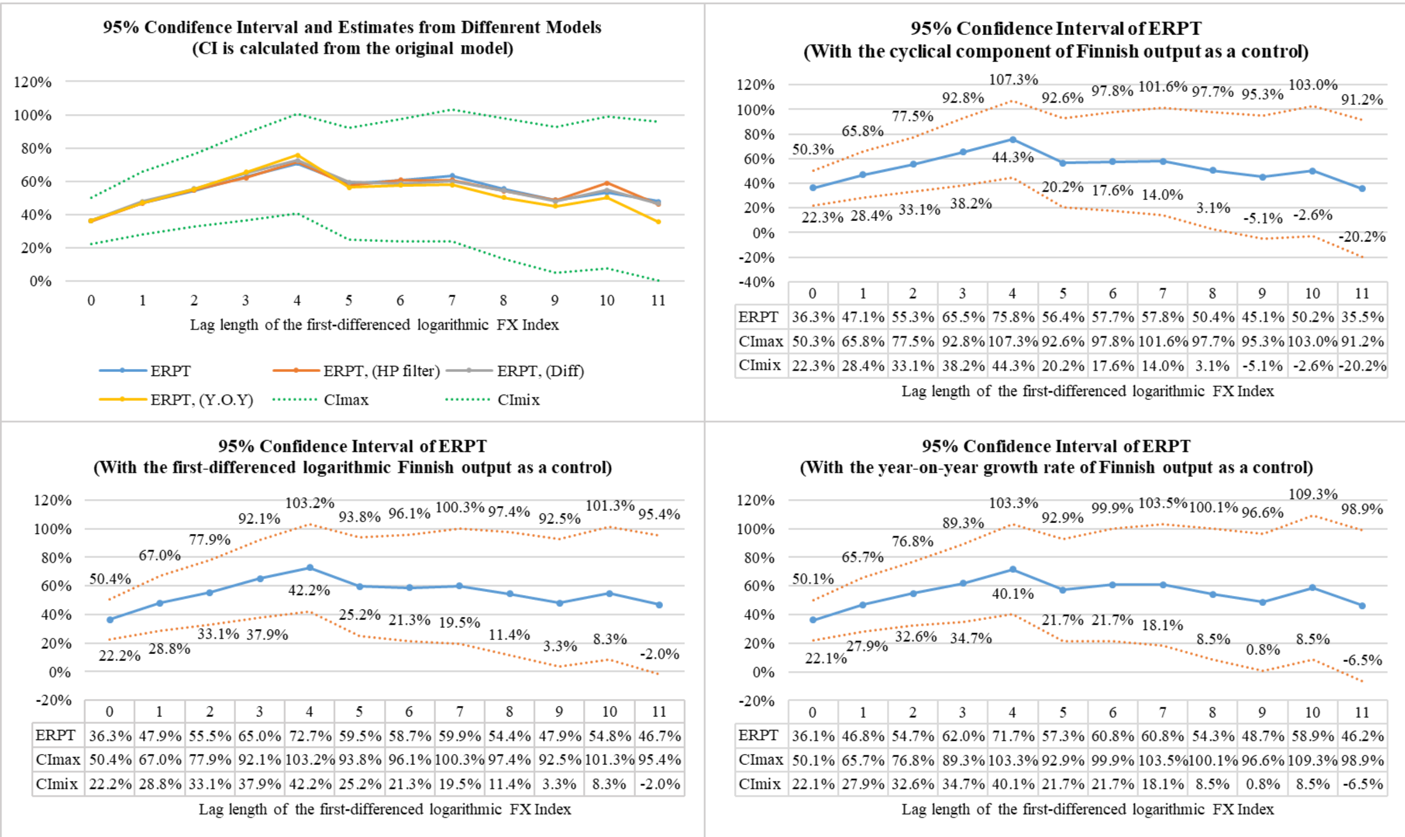


Figure 9 95% Confidence Interval of the Model with the Controlling Variable Formed by Different Method

In brief, three evidences can be concluded from the robustness check-up that the ERPT estimated from the original model is robust: ① The estimates from the model with or without the controlling variable are quite similar in general, although the model with the control of Finland's domestic demand slightly increases the ERPT estimated by the original model from the short term to the long term. ② The estimates of ERPT are always within the 95% confidence interval yielded from the original model without any controlling variable, regardless of the controlling method. Therefore, the estimates are not significantly different between the model with or without the controlling variable. ③ The 95% confidence interval of the model with the control of Finland's domestic demand aligns with that of the model without the control, especially when it is concerned with the defined short term to the long term.

6.3.2 Residual Diagnostics

A valid model requires no autocorrelation between the residual and the variables. The Ljung-Box Test is applied after running the regression of the model with or without the controlling variable. The null hypothesis of Ljung-Box Test is no autocorrelation between the residual and the variables. Table 10 below reports the *p*-value of the test in the model with or without controlling variable, all of which are big enough not to reject the null hypothesis of no autocorrelation. To further elaborate the validity of the model, Figure 10 in the next page plots the autocorrelation function (ACF) of the residual in the original model without any controlling variable (ACF of the model with the controlling variable can be found in Figure 18 in Appendix). Based on both the Ljung-Box Test and the residual's autocorrelation functions, we conclude that there is no autocorrelation between the residual and the variables, and the model is valid.

***p*-value Report from Ljung Box Test**												
Maximum lag length N_e (N_{fp}) of Δe_t (Δfp_t)	0	1	2	3	4	5	6	7	8	9	10	11
Original Model without any controlling variable	0.9669	0.9181	0.8846	0.8432	0.9813	0.939	0.9894	0.9941	0.9864	0.7637	0.8673	0.8171
Cyclical component of the output as the controlling variable	0.9533	0.9208	0.865	0.812	0.9369	0.9137	0.9435	0.9973	0.9449	0.756	0.9468	0.8319
First-differenced logged output as the controlling variable	0.9602	0.9271	0.8833	0.8588	0.7957	0.9858	0.9653	0.9997	0.9865	0.76	0.8836	0.8718
Year-on-year logged output as the controlling variable	0.9629	0.8812	0.9233	0.8948	0.9326	0.9418	0.9869	0.9458	0.9866	0.7457	0.8145	0.9159
Conclusion	Null hypothesis cannot be rejected no matter which lag length or model is chosen											

Table 10 p-value of Ljung-Box Test

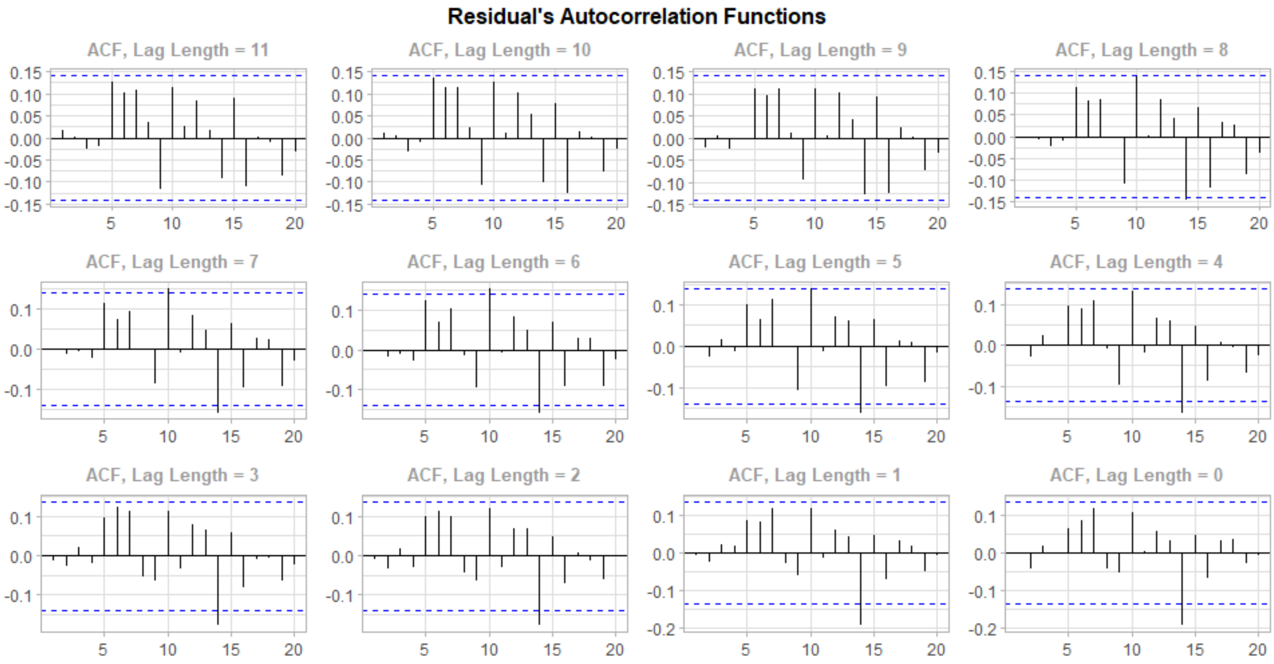


Figure 10 Residual's Autocorrelation Functions

7. Conclusion

Based on the modelling and the model diagnostics, we determined the long-term ERPT as the accumulated pass-through 4 months ahead of the current period, and we have also validated the estimates of ERPT in both the short term and the long term from the model without the control of Finland's domestic demand. Hence, we would suggest that the ERPT on Finnish import price is 36.5% in short term and 70.7% in long term. The short-term ERPT is significantly different from both 0 and 1; the long-term ERPT is significantly different from 0, but it cannot reject the alternative hypothesis of a full response in long term at 5% significant level.

Finland's domestic demand has little influence on the short-term ERPT, but it likely reduces ERPT by 1 to 5 percentage points in long term. The long-term ERPT 75.8% estimated with the control of Finland's domestic demand (cyclical component) is very close to Campa and Goldberg's (2005) estimate, 77%. Meanwhile, Finland's domestic demand partly explains the reason why the Finnish import prices do not fully respond to the exchange rate: high (low) domestic demand likely incentives the exporter to increase (decrease) the markup when pricing to Finnish market, while the increase (decrease) of Finnish import prices in this case is independent of the change of the exchange rate. The other reason explaining the partial pass-through may ascribe to two more factors: First, the countries out of EU, Russian, the U.S., China and Japan as Finland’s main trade partner, may have tighter policies on the cost, insurance and freight of the exports, while the EU area can be regarded as an integrated market without customs barrier, which causes that the change of Finland’s aggregated import prices deviates from the change of the aggregated exchange rate. Second, some Finnish companies use their foreign reserve to pay for the imports or convert Euro with the fixed exchange rate agreed in a customer contract with the suppliers, and the customer-specific exchange rate (Euro/Foreign currency) is usually smaller than the nominal exchange rate. Those behaviours could also twist the movement of Finnish import prices.

The study refers to the model in Campa and Goldberg’s (2005) work and improves the estimation of ERPT in five aspects: First, the empirical model takes the autoregression of the import prices as one additional right-hand variable. Second, the study chooses the PPI to describe price development of the exporter’s marginal cost, while CPI, with the wholesales margin and the retails margin, is employed in Campa and Goldberg’s analysis. Third, the study compares the calculation between the Unit Value Index and the Import Price Index, and the conclusion suggests Import Price Index is a better indicator to describe the price development of the imports; However, the Unit Value Index was applied in Campa and Goldberg’s analysis. Moreover, the long-term ERPT is this study is determined by the significance level of the estimate at each lag, instead of giving a fixed value to the maximum lag length as how the “long term” was decided in Campa and Goldberg’s model. Besides giving the significance level to the estimates of the ERPT referring both the null and alternative hypotheses, the study also calculates the standard error of the accumulated pass-through and illustrates the confidence interval.

However, the possible bias of the ERPT estimated in this study might be resulted from the data aggregate, where the weight for the monthly nominal exchange rate and the individual PPI of Finland’s trade partners is with annual frequency. The research concentrates on estimating and explaining the elasticity between the import prices and the aggregated exchange rate index, but the elasticity of the import prices with the respect to the aggregated foreign competing price and that of the import prices with the respect to the domestic demand, as the coefficients of foreign PPI and Finland’s output, are left unexplained, which can be a meaningful topic for extending the study on the pass-through effect.

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Appendix

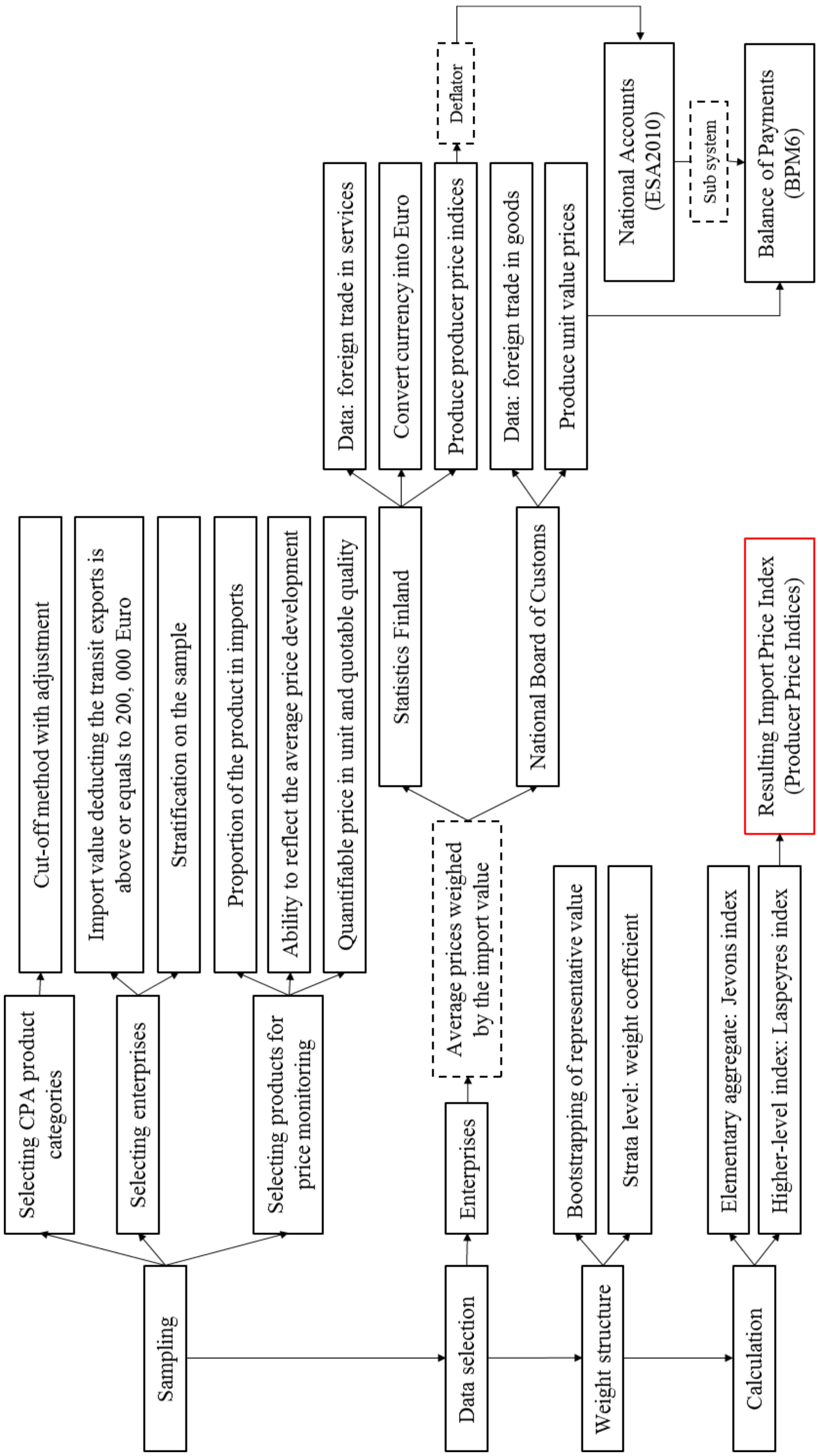


Figure 11 The Process of Producing Import Price Index

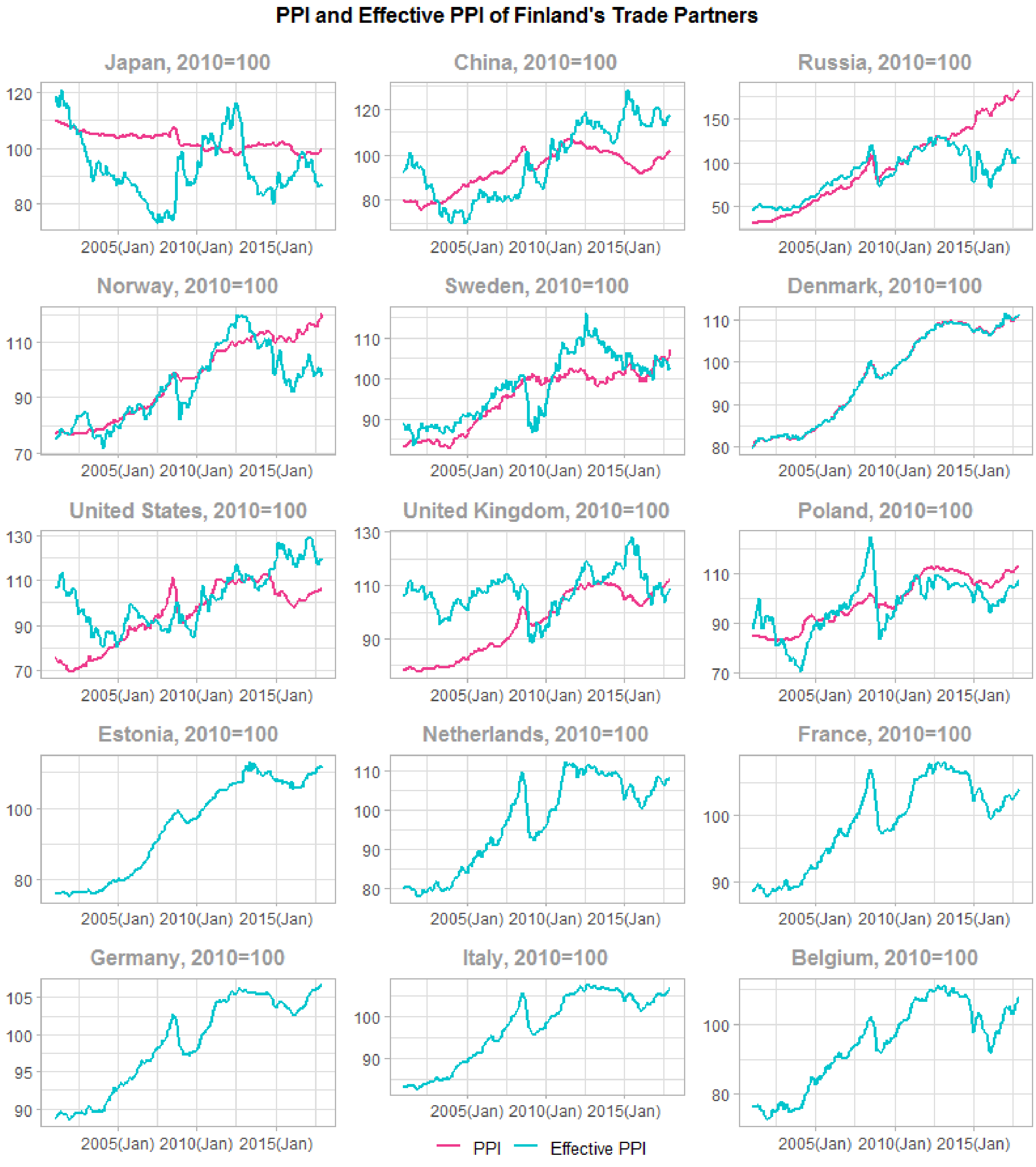


Figure 12 PPI and Effective PPI of Finland's Top 15 Trade Partners

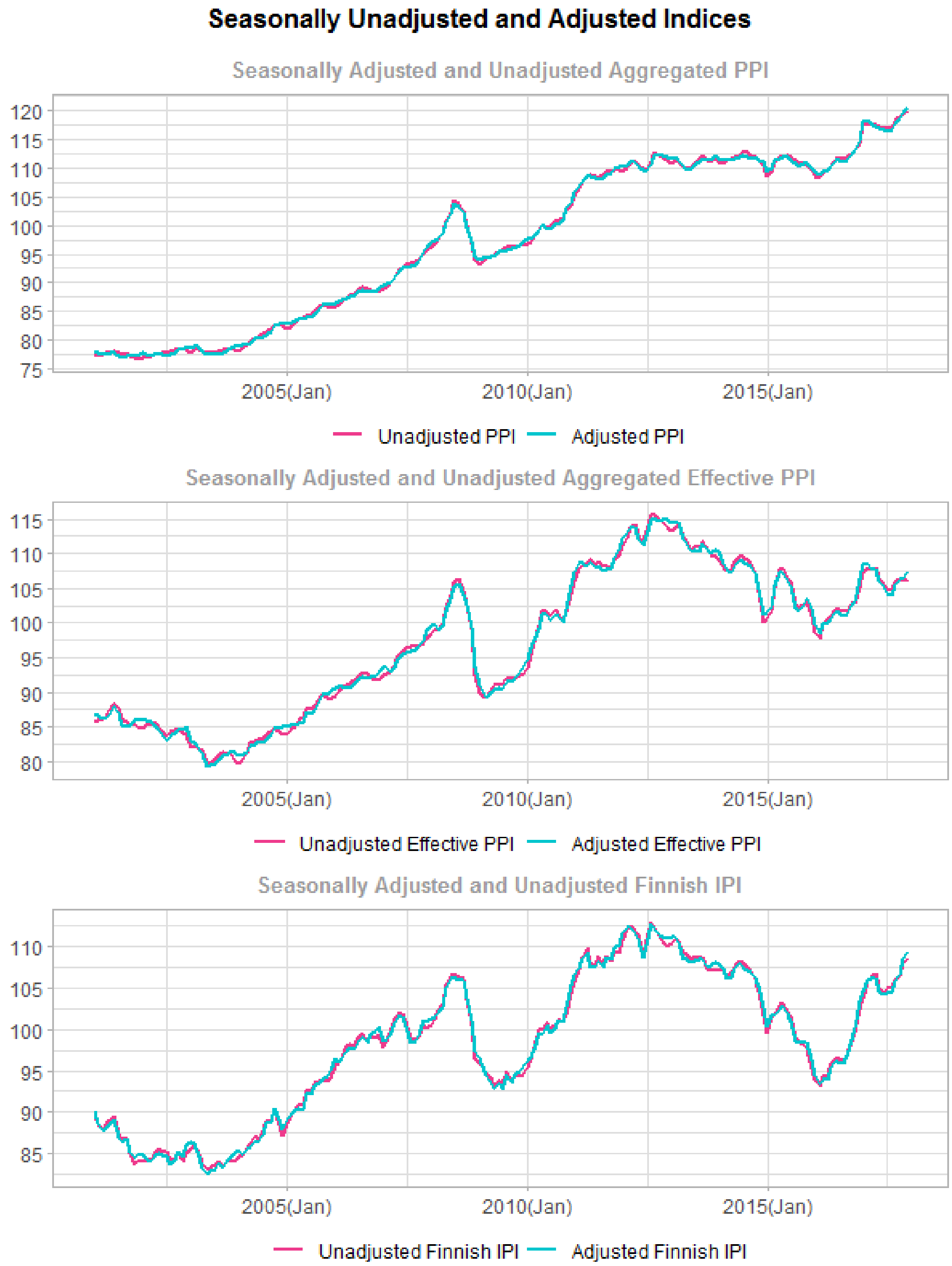


Figure 13 Seasonally Unadjusted and Adjusted Indices

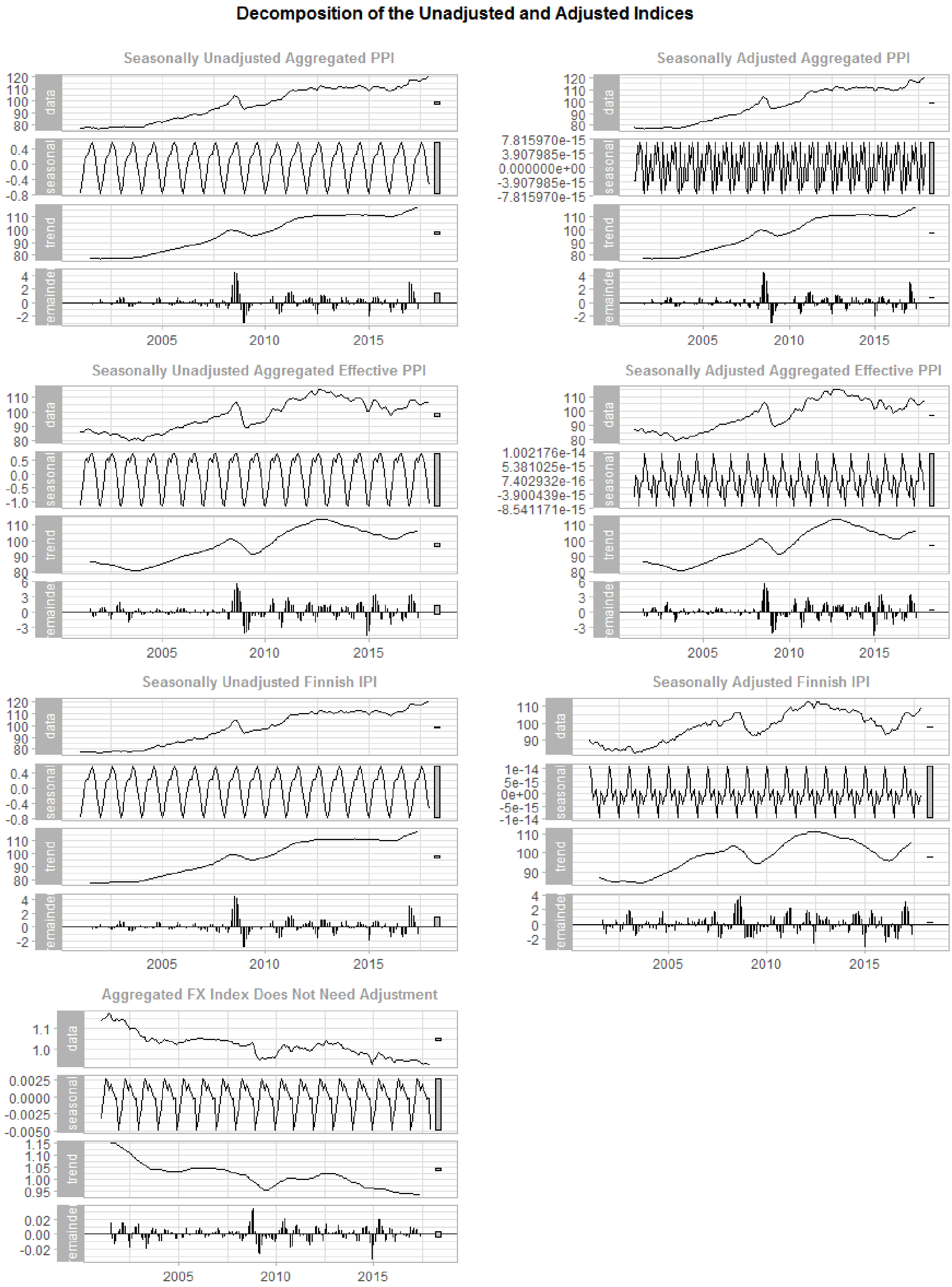


Figure 14 Decomposition of the Unadjusted and Adjusted Indices

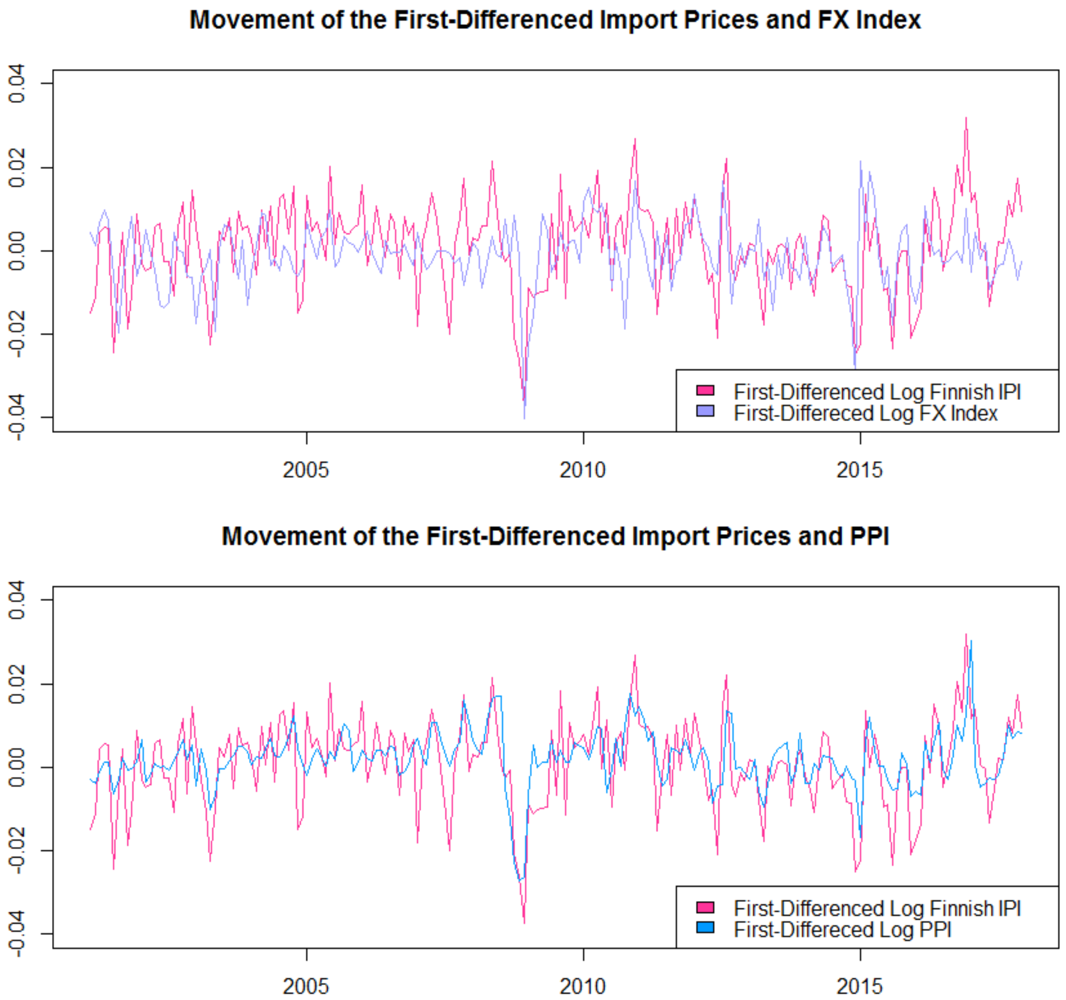


Figure 15 The Movements of the First-Differenced Variables in the Model without Controlling Variable

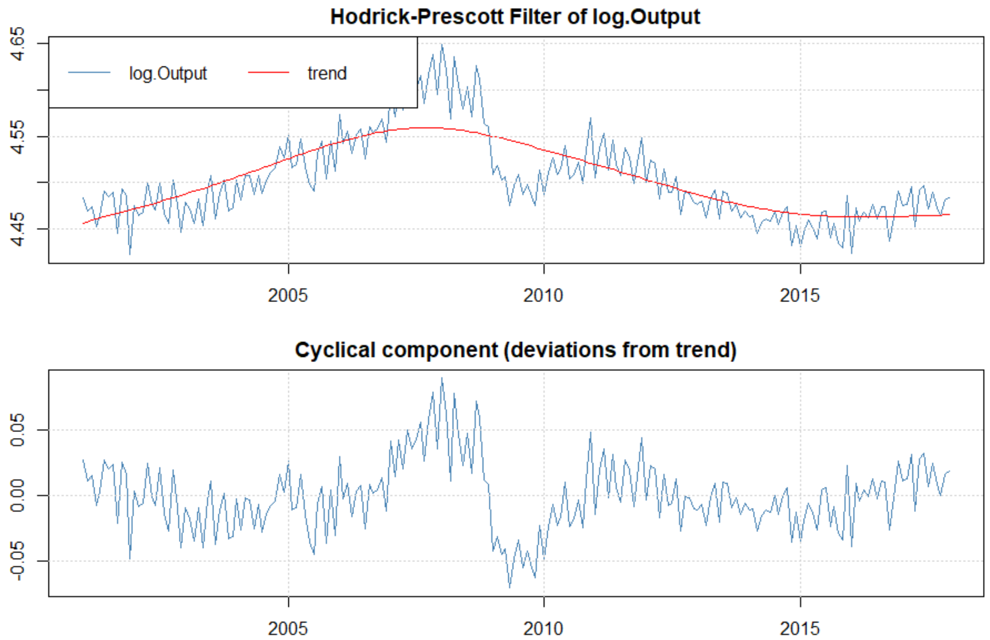


Figure 16 The Cyclical Component of Finland's Monthly Domestic Demand (Lambda=129600)

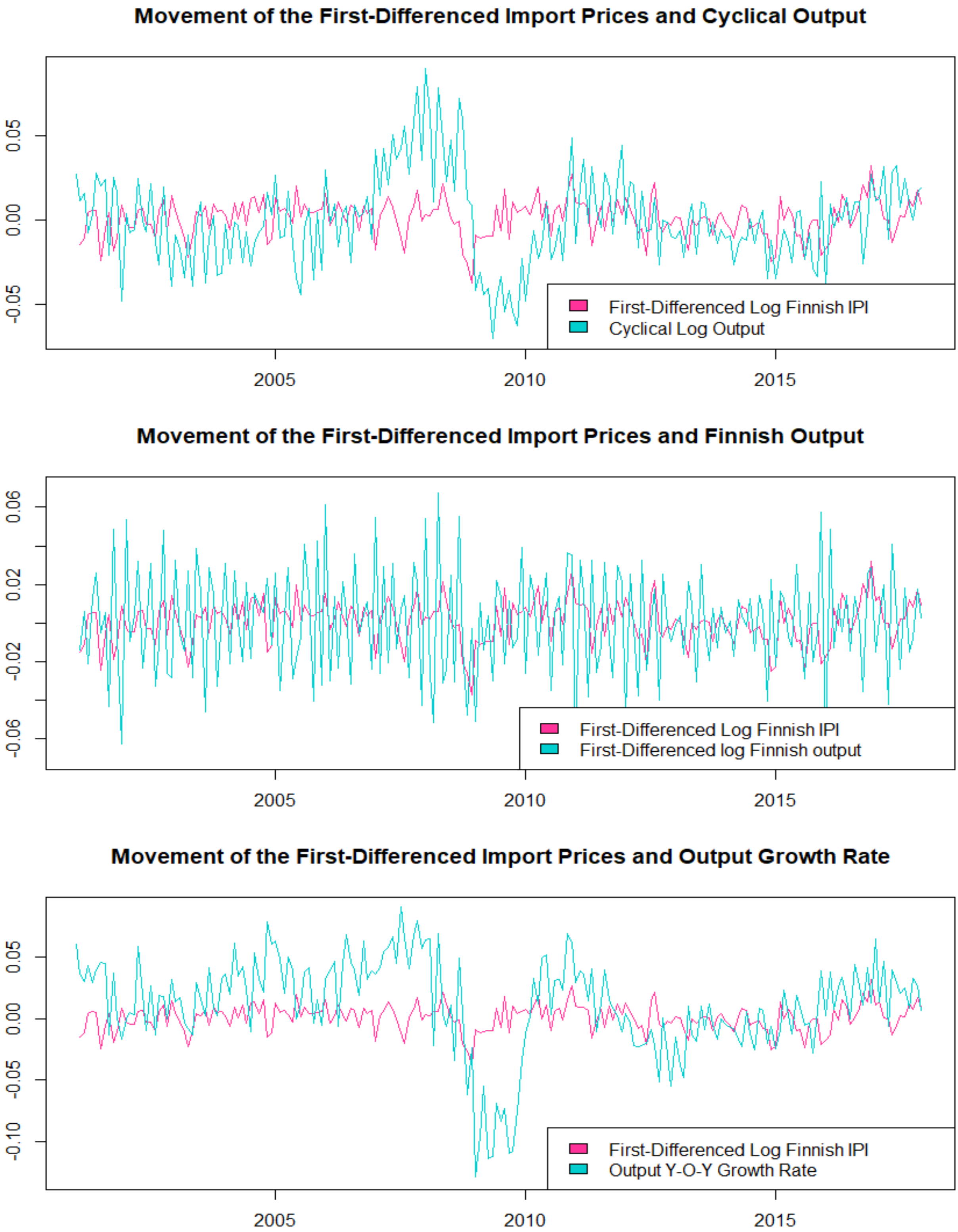
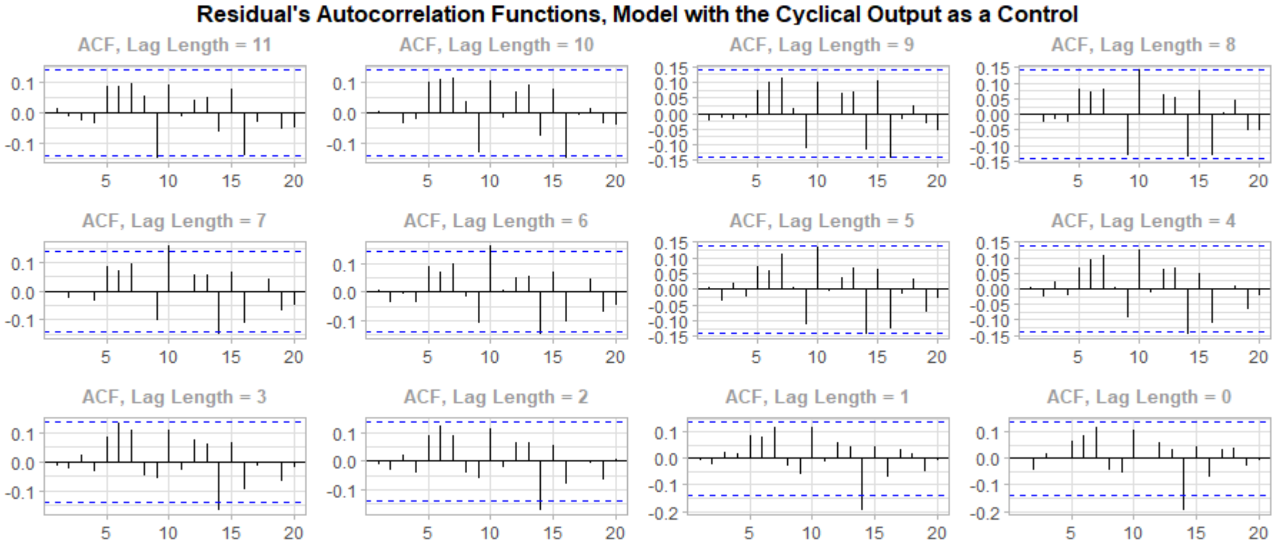
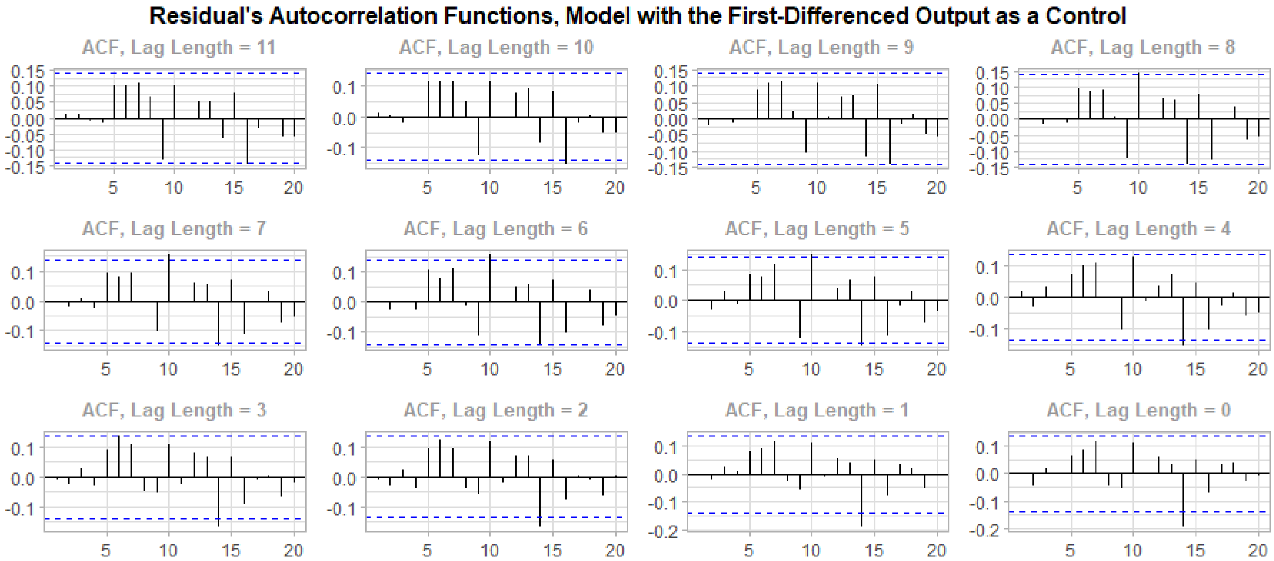


Figure 17 The Process of the Controlling Variable Formed with Different Method





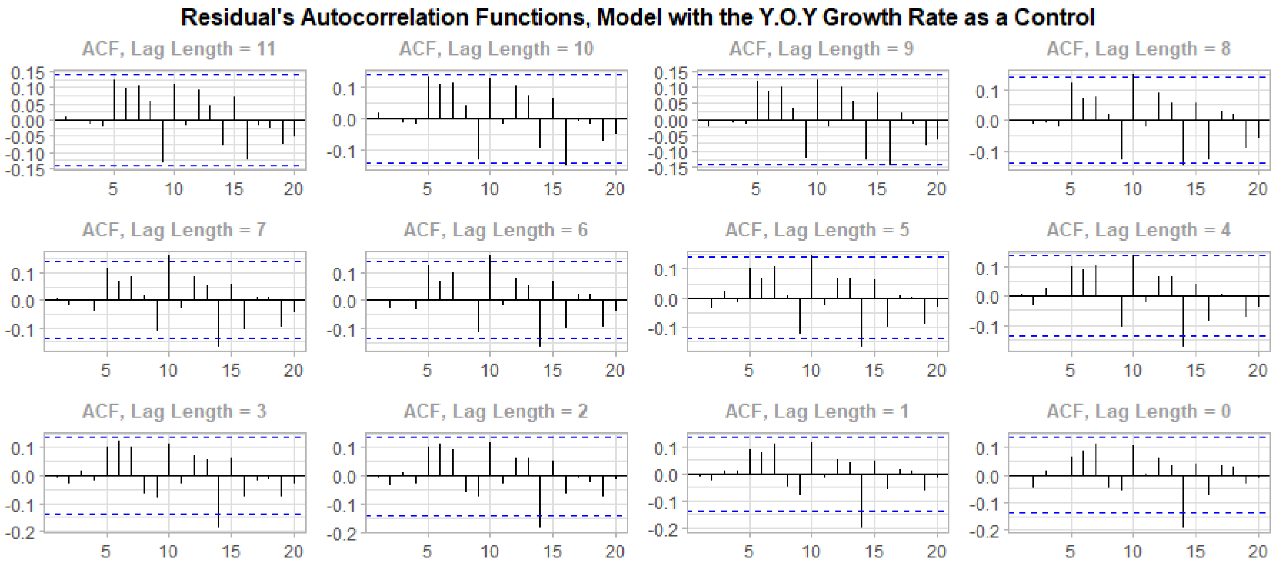


Figure 18 Residual's ADF from the Model with the Controlling Variable formed by Different Method

Result of ERPT with the Control of Finland's Domestic Demand

(The controlling variable is derived from the cyclical component in Hodrick-Prescott Filter)

AIC selected 1 lag for Δp_{t-k}, $N_p = 1$:

$$\Delta p_t = c + \sum_{k=1}^{N_p=1} \alpha_k \Delta p_{t-k} + \sum_{k=0}^{N_e} \beta_k \Delta e_{t-k} + \sum_{k=0}^{N_{fp}} \gamma_k \Delta fp_{t-k} + \sum_{k=0}^{N_y} \theta_k y_{t-k} + v$$

Lags for Δe_t and Δfp_t	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}	$\sum_{k=0}^{N_e} \beta_k$
$N_e = N_{fp} = 0$	0.363*** (0.071)												0.360 (0.071)
$N_e = N_{fp} = 1$	0.344*** (0.077)	0.127 (0.079)											0.471 (0.096)
$N_e = N_{fp} = 2$	0.382*** (0.078)	0.060 (0.083)	0.111 (0.074)										0.553 (0.113)
$N_e = N_{fp} = 3$	0.399*** (0.082)	0.079 (0.087)	0.077 (0.081)	0.100 (0.076)									0.655 (0.139)
$N_e = N_{fp} = 4$	0.392*** (0.082)	0.096 (0.088)	0.111 (0.082)	0.016 (0.081)	0.143. (0.076)								0.758 (0.161)
$N_e = N_{fp} = 5$	0.394*** (0.082)	0.077 (0.088)	0.062 (0.084)	-0.023 (0.082)	0.156. (0.080)	-0.101 (0.075)							0.564 (0.181)
$N_e = N_{fp} = 6$	0.392 (0.083)	0.078 (0.089)	0.072 (0.084)	-0.015 (0.085)	0.179* (0.083)	-0.103 (0.082)	-0.026 (0.077)						0.577 (0.199)
$N_e = N_{fp} = 7$	0.397*** (0.084)	0.077 (0.091)	0.067 (0.086)	-0.015 (0.086)	0.180* (0.086)	-0.118 (0.085)	-0.011 (0.084)	0.001 (0.077)					0.578 (0.218)
$N_e = N_{fp} = 8$	0.388*** (0.086)	0.085 (0.093)	0.069 (0.087)	-0.023 (0.088)	0.168. (0.087)	-0.136 (0.088)	0.004 (0.087)	-0.020 (0.084)	-0.031 (0.077)				0.504 (0.234)
$N_e = N_{fp} = 9$	0.398*** (0.085)	0.093 (0.092)	0.040 (0.087)	-0.024 (0.087)	0.184* (0.087)	-0.126 (0.088)	-0.001 (0.088)	-0.014 (0.085)	-0.018 (0.083)	-0.080 (0.078)			0.451 (0.244)
$N_e = N_{fp} = 10$	0.419*** (0.087)	0.093 (0.093)	0.036 (0.088)	-0.031 (0.088)	0.167. (0.088)	-0.102 (0.089)	-0.006 (0.089)	-0.010 (0.088)	-0.004 (0.086)	-0.116 (0.085)	0.055 (0.079)		0.502 (0.257)
$N_e = N_{fp} = 11$	0.421*** (0.088)	0.078 (0.096)	0.029 (0.088)	-0.047 (0.089)	0.191* (0.089)	-0.101 (0.090)	-0.018 (0.090)	-0.035 (0.088)	-0.038 (0.088)	-0.126 (0.088)	0.037 (0.086)	-0.036 (0.079)	0.355 (0.269)

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 11 ERPT Reported from the Model with the Cyclical Component of Output as the Controlling Variable

Result of ERPT with the Control of Finland's Domestic Demand

(The controlling variable is the first-differenced logarithmic trend indicator of output)

AIC selected 1 lag forΔp_{t-k}, $N_p = 1$:

$$\Delta p_t = c + \sum_{k=1}^{N_p=1} \alpha_k \Delta p_{t-k} + \sum_{k=0}^{N_e} \beta_k \Delta e_{t-k} + \sum_{k=0}^{N_{fp}} \gamma_k \Delta fp_{t-k} + \sum_{k=0}^{N_y} \theta_k y_{t-k} + v$$

Lags for Δe_t and Δfp_t	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}	$\sum_{k=0}^{N_e} \beta_k$
$N_e = N_{fp} = 0$	0.363*** (0.072)												0.363 (0.072)
$N_e = N_{fp} = 1$	0.353*** (0.078)	0.126 (0.079)											0.479 (0.097)
$N_e = N_{fp} = 2$	0.382*** (0.078)	0.063 (0.085)	0.111 (0.074)										0.555 (0.114)
$N_e = N_{fp} = 3$	0.396*** (0.081)	0.077 (0.087)	0.081 (0.082)	0.096 (0.076)									0.65 (0.138)
$N_e = N_{fp} = 4$	0.410*** (0.080)	0.092 (0.087)	0.093 (0.081)	-0.014 (0.081)	0.145. (0.075)								0.727 (0.155)
$N_e = N_{fp} = 5$	0.407*** (0.081)	0.069 (0.089)	0.067 (0.083)	-0.014 (0.083)	0.175* (0.081)	-0.109 (0.075)							0.595 (0.175)
$N_e = N_{fp} = 6$	0.401*** (0.081)	0.077 (0.089)	0.081 (0.084)	-0.014 (0.084)	0.175* (0.083)	-0.109 (0.083)	-0.024 (0.077)						0.587 (0.191)
$N_e = N_{fp} = 7$	0.401*** (0.084)	0.077 (0.091)	0.072 (0.086)	-0.015 (0.086)	0.181* (0.085)	-0.118 (0.085)	-0.000 (0.085)	0.000 (0.077)					0.599 (0.206)
$N_e = N_{fp} = 8$	0.397*** (0.085)	0.085 (0.093)	0.076 (0.087)	-0.017 (0.087)	0.174* (0.086)	-0.134 (0.088)	0.009 (0.087)	-0.011 (0.085)	-0.034 (0.078)				0.544 (0.220)
$N_e = N_{fp} = 9$	0.407*** (0.084)	0.095 (0.092)	0.044 (0.087)	-0.018 (0.087)	0.189* (0.086)	-0.123 (0.087)	0.004 (0.088)	-0.016 (0.085)	-0.014 (0.084)	-0.087 (0.078)			0.479 (0.228)
$N_e = N_{fp} = 10$	0.435*** (0.086)	0.093 (0.093)	0.050 (0.088)	-0.025 (0.088)	0.178* (0.087)	-0.099 (0.088)	0.010 (0.089)	-0.008 (0.087)	-0.009 (0.086)	-0.127 (0.087)	0.050 (0.079)		0.548 (0.237)
$N_e = N_{fp} = 11$	0.444*** (0.088)	0.084 (0.096)	0.046 (0.088)	-0.032 (0.089)	0.204* (0.088)	-0.087 (0.089)	-0.004 (0.090)	-0.021 (0.088)	-0.028 (0.087)	-0.130 (0.088)	0.038 (0.087)	-0.047 (0.079)	0.467 (0.249)

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 12 ERPT Reported from the Model with the First-Differenced Logarithmic Output as the Controlling Variable

Result of ERPT with the Control of Finland's Domestic Demand

(The controlling variable is the Y.O.Y logarithmic trend indicator of output)

AIC selected 1 lag for Δp_{t-k}, $N_p = 1$:

$$\Delta p_t = c + \sum_{k=1}^{N_p=1} \alpha_k \Delta p_{t-k} + \sum_{k=0}^{N_e} \beta_k \Delta e_{t-k} + \sum_{k=0}^{N_{fp}} \gamma_k \Delta fp_{t-k} + \sum_{k=0}^{N_y} \theta_k y_{t-k} + v$$

Lags for Δe_t and Δfp_t	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}	$\sum_{k=0}^{N_e} \beta_k$
$N_e = N_{fp} = 0$	0.363*** (0.072)												0.361 (0.072)
$N_e = N_{fp} = 1$	0.353*** (0.078)	0.126 (0.079)											0.468 (0.096)
$N_e = N_{fp} = 2$	0.382*** (0.078)	0.063 (0.085)	0.111 (0.074)										0.547 (0.113)
$N_e = N_{fp} = 3$	0.396*** (0.081)	0.077 (0.087)	0.081 (0.082)	0.096 (0.076)									0.62 (0.139)
$N_e = N_{fp} = 4$	0.410*** (0.080)	0.092 (0.087)	0.093 (0.081)	-0.014 (0.081)	0.145. (0.075)								0.717 (0.161)
$N_e = N_{fp} = 5$	0.407*** (0.081)	0.069 (0.089)	0.067 (0.083)	-0.014 (0.083)	0.175* (0.081)	-0.109 (0.075)							0.573 (0.185)
$N_e = N_{fp} = 6$	0.401*** (0.081)	0.077 (0.089)	0.081 (0.084)	-0.014 (0.084)	0.175* (0.083)	-0.109 (0.083)	-0.024 (0.077)						0.608 (0.205)
$N_e = N_{fp} = 7$	0.401*** (0.084)	0.077 (0.091)	0.072 (0.086)	-0.015 (0.086)	0.181* (0.085)	-0.118 (0.085)	-0.000 (0.085)	0.000 (0.077)					0.608 (0.224)
$N_e = N_{fp} = 8$	0.397*** (0.085)	0.085 (0.093)	0.076 (0.087)	-0.017 (0.087)	0.174* (0.086)	-0.134 (0.088)	0.009 (0.087)	-0.011 (0.085)	-0.034 (0.078)				0.543 (0.241)
$N_e = N_{fp} = 9$	0.407*** (0.084)	0.095 (0.092)	0.044 (0.087)	-0.018 (0.087)	0.189* (0.086)	-0.123 (0.087)	0.004 (0.088)	-0.016 (0.085)	-0.014 (0.084)	-0.087 (0.078)			0.487 (0.256)
$N_e = N_{fp} = 10$	0.435*** (0.086)	0.093 (0.093)	0.050 (0.088)	-0.025 (0.088)	0.178* (0.087)	-0.099 (0.088)	0.010 (0.089)	-0.008 (0.087)	-0.009 (0.086)	-0.127 (0.087)	0.050 (0.079)		0.589 (0.269)
$N_e = N_{fp} = 11$	0.444*** (0.088)	0.084 (0.096)	0.046 (0.088)	-0.032 (0.089)	0.204* (0.088)	-0.087 (0.089)	-0.004 (0.090)	-0.021 (0.088)	-0.028 (0.087)	-0.130 (0.088)	0.038 (0.087)	-0.047 (0.079)	0.462 (0.284)

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 13 ERPT Reported from the Model with the Year-on-Year Logarithmic Output as the Controlling Variable